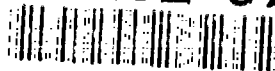


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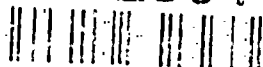
A RAND NOTE

Case Study of Risk Management in the
USAF B-1B Bomber Program

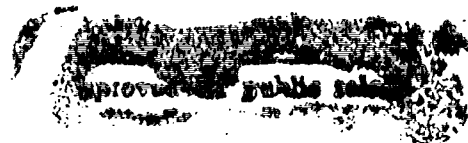
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A RAND NOTE

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Case Study of Risk Management in the USAF B-1B Bomber Program

Susan J. Bodilly

Prepared for the
United States Air Force

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PREFACE

This Note presents one of seven case studies of the development of major weapons systems carried out as part of the Project AIR FORCE study "Managing Risks in Weapon Systems Development Programs." The larger study addresses the manner in which government policies and practices shape the management of risk during the design and development of major weapons systems. The study is intended primarily for higher-level Air Force, Department of Defense (DOD), and congressional personnel who create the environment and policies governing the acquisition process. However, the overall study and the supporting case studies should also be useful to policy analysts concerned with the management of large-scale research and development programs, particularly in the DoD.

Several criteria were used to determine which cases might be usefully explored for insights into how to improve risk management during procurement. The program had to be started in the midseventies or later for the researchers to have access to documents and managers for interviews. The project had to be a major weapon system, with both the Office of the Secretary of Defense (OSD) and congressional officials involved, to represent the complexity of the decision environment. A representative cross section of types of development situations was chosen by varying the type of systems developed, the size of the program, and the degree of technical risk involved.

The seven programs chosen were AMRAAM, the advanced fighter engine, the B-1B bomber, the F-16 MSIP, the Global Positioning System (GPS), JSTARS, and LANTIRN. Two case studies in the series, on GPS and JSTARS, are authored by Tim Webb, but as yet are unpublished. The five remaining cases in the series are documented in the following Notes:

- Susan J. Bodilly, *Case Study of Risk Management in the USAF B-1B Bomber Program*, N-3616-AF, 1993.
- Susan J. Bodilly, *Case Study of Risk Management in the USAF LANTIRN Program*, N-3617-AF, 1993.
- F. Camm, *The Development of the F100-PW-220 and F110-GE-100 Engines: A Case Study of Risk Assessment and Risk Management*, N-3618-AF, 1993.
- F. Camm, *The F-16 Multinational Staged Improvement Program: A Case Study of Risk Assessment and Risk Management*, N-3619-AF, 1993.

- K. R. Mayer, *The Development of the Advanced Medium-Range Air-to-Air Missile: A Case Study of Risk and Reward in Weapon System Acquisition*, N-3620-AF, 1993.

The Air Force sponsor for these studies is the Deputy Assistant Secretary of the Air Force (Contracting) (SAF/AQC). The work was conducted in the Resource Management Program of Project AIR FORCE.

SUMMARY

This case study was undertaken in conjunction with six others to develop a better understanding of the risks involved in weapon system development and whether government policies effectively aid in the management of those risks to reduce the probability or severity of negative outcomes. The purpose of the larger study of seven Air Force procurement programs is to provide information that might improve the decision environment in which weapon systems are procured and thus to increase the probability of positive outcomes.

This case focuses on the procurement of the B-1B bomber and covers the procurement of the entire aircraft platform and its component systems. The B-1B, with a direct program acquisition cost of \$20.5 billion in 1981 dollars, represents a mixed array of technical advances depending on the component part examined. The case study identifies risk-related decisions made early in the program prior to or at the start of full-scale development. The assessments of risk and its subsequent management are then tracked to show how the early risk management decisions affected the program.

The term risk, as used throughout this paper, is the probability that, given that an activity is undertaken, an event will occur that has negative outcomes for those involved. This case study (1) identifies acquisition practices that shape and manage risk and (2) suggests possible improvements.

B-1B CONTROVERSY

On the one hand, the B-1B bomber procurement has been hailed as a great success in Air Force history, producing the most advanced bomber ever built. After 35 years of trying, the Air Force procured 100 bombers to replace the B-52s. The B-1B was produced on schedule and largely on budget.

On the other hand, this procurement has also been described as a major catastrophe. Some claim the Air Force procured a plane that cannot perform its mission significantly better than the B-52s it was supposed to replace. The additional expenditures needed to bring the aircraft up to the originally expected performance levels could be on the order of several billion dollars. Mitigating this is the fact that the presently estimated corrective cost (\$1.9 billion) represents only a 7 percent cost overrun. Of course, whether this expenditure will in fact meet the performance goals is uncertain.

The complex, and very contentious, story can be summarized simply. After years of work to get approval of a new advanced bomber, the Air Force procured the B-1B during a

period of rapidly growing defense spending. The pro-defense environment and the inclusion of the proposed program in presidential campaign promises ensured that B-1B program decisions were made at the highest levels of government in a political negotiation far removed from the more routine acquisition process controlled by career acquisition experts in System Program Offices (SPOs). These high government levels imposed constraints on the B-1B program that increased the probability of negative outcomes in the program, reducing the flexibility of the SPO to manage the inherent technical risk in the program.

Congress, with agreement by the administration, imposed several constraints on the program: it would have an initial operational capability (IOC) by 1987, it would not exceed a \$20.5 billion budget cap in 1981 dollars, and the government would act as system integrator. In exchange, all parties committed to stable requirements, quantities, and funding.

These macroconstraints, in essence a management strategy, produced, perhaps inadvertently, incentives within the program to meet cost and schedule goals and to emphasize them in reporting program progress. When the program encountered technical difficulties, the budget cap and IOC date acted as constraints on SPO actions, inhibiting its ability to manage well. The only unconstrained area was performance. The program could always meet the budget and schedule constraints by not meeting performance goals. This is in fact what occurred.

Although the program ran close to budget and on schedule, the performance of the aircraft has been a problem to which even proponents admit. Further, the pro-defense environment evaporated as the program progressed. Thus, when difficulties came to light, they were evaluated in a more adversarial light than when the program started.

LESSONS LEARNED ABOUT RISK MANAGEMENT

This case study highlights the potential risks that can be imposed by high-level government actions, especially when these actions reduce the ability of the SPO to respond flexibly to technical difficulties. The story told is not about mismanagement at lower levels. Instead it focuses on the initial conditions set at high levels and their strong impacts, some negative, on lower-level management actions. The following lessons concerning risk management can be taken from the B-1B program.

Concurrency does not produce the desired results on programs with technical risk if the program management strategy does not include the resources and flexibility to deal with risk. When technical problems arose, the SPO had no latitude to deal with them, which allowed the problems to continue. It was the combination of constraints on this technically risky program that increased the probability of negative outcomes. The problem evidenced on the

B-1B was not concurrency itself, but concurrency combined with high technical risk in areas important to operational capability together with lack of management leeway. This combination simply does not work well.

Narrow indicators of program progress allowed the program to proceed without raising the red flags necessary for good risk management. The indicators used focused on two areas: cost and schedule. In a highly concurrent program, the technical difficulties would not impact on the schedule or cost until production aircraft had been built. While full-scale development dollars would mount, this would not necessarily result in exceeding the cap until later in the program. Strict adherence to the cost and schedule constraints meant that when technical difficulties arose, performance *had to* slip. With more flexibility, the SPO might have chosen a more desirable alternative.

The final outcome under this set of constraints was an aircraft produced close to on-time and on-budget that still does not meet the operational capabilities defined as essential in the early advocacy of the program. This is a result no one wanted.

ACKNOWLEDGMENTS

This research would not have been possible without the assistance of the members of Air Force Systems Command History Office and former and current members of the B-1B Program Office. My colleagues at RAND also offered valuable assistance and commentary: Frank Camm, George L. Donohue, Thomas K. Glennan, Michael Kennedy, Kenneth Mayer, Giles K. Smith, and Timothy Webb. Most important was the excellent assistance of Luetta Pope.

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1. INTRODUCTION

PROBLEM

Weapon system development involves the risk of failure to achieve planned outcomes. The risk of failure involves not meeting planning expectations: failure to produce the performance sought for a particular aggregation of technologies, within a specific time anticipated, for the cost anticipated. This definition of risk is described in more detail in the appendix.

These failures are felt not only by engineers and line operators who design and construct weapon systems, but also by government policymakers, business executives, and elected officials. These actors are exposed to risk of loss of different magnitudes, affecting different numbers of people in different ways. But all these actors share a common need to avoid or reduce risks or to effectively manage them.

The United States Department of Defense (DoD) has investigated and tested many ways to manage risk in an ongoing effort to avoid failures. The impetus of many defense reform initiatives has been dissatisfaction with exposure to risk or actual risks incurred. This case study attempts to contribute to the effort to reduce the risks involved in the weapon system acquisition programs.

RESEARCH OBJECTIVES

The objectives of this study are to

- Identify acquisition practices and institutional incentives that shape the risk of failure for individuals and organizations;
- Better understand the ways in which exposure to risks can be managed by Air Force System Program Offices (SPOs); and
- Suggest improvements in current policies and practices that affect risk management.

RESEARCH APPROACH AND SCOPE

This study reviews the history of one weapon system development, that of the B-1B bomber. It focuses on events that reveal how risks were managed and on barriers to the management of risks. The case study materials were collected from a literature review and interviews with officials formerly connected to the B-1B procurement. The literature reviewed included newspaper, journal, and magazine accounts; formal Air Force documents

collected by the B-1B SPO; and others' written accounts of the program, especially Air Force histories.

The B-1B procurement has ended—no more bombers will be procured. However, the Air Force is still considering possible improvements to the current force. This study ends in 1990, with the completion of the final aircraft and the subsequent discussion of improvements; it does not update this discussion to the present.

THE B-1B PROGRAM AND ITS RISKS

The B-1B bomber represents the acquisition of an entire aircraft platform and its component systems. The B-1B was the most costly Air Force procurement in the time period studied, with direct costs equaling approximately \$20.5 billion in 1981 dollars, the base year of the program.

Like the other cases studied, the B-1B development had associated technical risk. The design of the plane was based on that of a predecessor, the B-1A. Technical difficulties with the B-1A had not been completely solved. These included problems with movement in the swept wings, roll control, fuel leaks, vibrations in the weapons bay doors, and false alarms in the central control avionics systems. These potential technical difficulties were incorporated into the design of the B-1B and were recognized in the acquisition plan. In addition, the plan also recognized that the design incorporated technical advances over the B-1A (for example, greater gross weight and improved offensive and defensive avionics systems). Review of the contractual arrangements for the B-1B indicates that the Air Force and the contractor recognized these risks early in the development of the program.

Unlike the management plans of the other systems studied, that for the B-1B had many constraints that reduced the flexibility of the SPO to manage these technical risks. The SPO did not develop the B-1B management plan, as is normally the case. Instead, the plan developed out of negotiations between Congress and the administration over a bomber program. This negotiation resulted in several constraints: a firm initial operational capability (IOC) date, resulting concurrency to the extent that development and production completely overlapped, a firm cost cap on the program, a multiyear contract, and the Air Force acceptance of the role of system integrator to reduce costs. Added to these management constraints was an additional potential problem. The B-1B program was in the limelight of defense issues. Any problems would be held up to very public scrutiny.

While each of these had been imposed individually on programs before, this was the first time that all of these constraints had been combined in a single program. Together they acted to prevent the SPO from managing the technical risk of the program. Acting under

these unusual constraints, the SPO developed and produced the 100 B-1Bs required. It met the IOC date and the cost cap. However, technical difficulties caused performance to suffer.

In general, this management plan had detrimental effects, but one positive effect was evident. The program did not suffer from requirements changes or the threat of cancellation. All parties, the Congress and the administration, had committed to the program. In this way the SPO did have stable working conditions—a situation not often experienced by acquisition programs.

ORGANIZATION OF THE NOTE

The rest of this Note is organized to highlight the events leading to the management plan, its reasonableness given technical issues in the B-1B development, the early recognition of technical difficulties as evidenced by the contractual difficulties, and the ultimate program outcomes.

The rest of the report is organized as follows. Section 2 covers the early history of the bomber program; the events leading to the program management plan are reviewed. The details of the management plan or program structure are analyzed in Section 3 in terms of general risks to any program, regardless of the technical risk inherent in the B-1B. The plan is then reviewed in Section 4 in light of the technical risk evident in the program at full-scale development (FSD). In Section 5 the Note examines the contractual structure to show how the government was the major risk bearer in the program. Next, Section 6 reviews the FSD phase, including the technical and organizational issues. Conclusions are then drawn.

2. THE B-1B DECISION AND RESULTING MANAGEMENT PLAN

The story of the B-1B procurement begins long before President Reagan's decision in 1981 to build the B-1B bomber and its completion in 1988. Only the broadest outline of the efforts of the Air Force prior to 1981 to acquire a bomber to replace the B-52 will be recounted here. Other histories with abundant detail are available.¹

THE B-1A

Starting in 1954, before the B-52 bombers had been produced, the Air Force began to consider what the B-52 replacement should be. It made several attempts, the B-58 and B-70, to gain congressional support for acquiring a new bomber but never was able to gain support for a complete production run.

The perceived need for a new bomber was fueled by the downing of the U-2 spy plane over the Soviet Union in 1960. The U-2 flew at very high altitudes, yet had been shot down by the Soviet's radar-guided surface-to-air missile (SAM). The implications were clear. Any new penetrating bomber would have to travel to enemy airspace at high altitude to conserve fuel. It would then penetrate to its target at low altitude, but high speed, to avoid radar detection and SAM attack.

In 1969 the Air Force solicited requests for proposals for a new bomber design that combined supersonic cruise capability at high altitude with subsonic, low-altitude penetration of enemy defenses. The winning design, which became the B-1A, was proposed by the North American Aircraft Division of Rockwell International,² together with General Electric as the engine supplier. Later, the Air Force selected Airborne Instrument Laboratory (AIL) to develop the defensive avionics and Boeing to develop the offensive

¹For a history of the bomber program the following sources are available. Steven Pace, *North American Valkyrie XB-70A*, Aero Publishers, Inc., Fallbrook, CA, 1984; William Holder, *The B-1 Bomber*, Tab Books, Blue Ridge Summit, PA, 1986; Nick Kotz, *Wild Blue Yonder, Money, Politics and the B-1 Bomber*, Princeton University Press, Princeton, NJ, 1988; Michael Taylor, *Jane's World Combat Aircraft*, Jane's Information Group, 1988; Marcelle Size Knaack, *Encyclopedia of U.S. Air Force Aircraft and Missile Systems, Post-WWII Bombers 1945-1973*, Vol. III, Office of Air Force History, United States Air Force, Washington, D.C., 1988.

²North American Aviation, Inc., was incorporated in Delaware in 1928. It merged in 1967 with Rockwell-Standard of Pittsburgh, PA. The corporate name was changed to Rockwell International Corporation in 1973. Rockwell has four major businesses: aerospace, automotive, electronics, and general industries. North American Aircraft is an operating unit of Rockwell and produces bombers. For the purposes of this discussion, North American and Rockwell are the same company and have been a continuous presence in the Air Force bomber program.

avionics. A production run of 250 aircraft to meet the Air Force's stated requirement was planned.

Political support for the bomber waned in the midseventies. A growing coalition of congressmen were against military spending as part of a reaction to the Vietnam War. But it was also because the manned, strategic penetration mission was questioned by many observers, especially President Carter.³

Both administration and congressional support also receded because of problems within the program itself. The development was well behind schedule and was having substantial cost overruns.

Faced with a weak defense of its mission, Congress was not in the mood to support a program that appeared to be poorly managed. In 1975, the Congress directed that the Air Force justify the need for the bomber program or it would be cancelled.

Congressional action was preempted by the president. In 1977, Jimmy Carter cancelled the program with three bombers built. A fourth bomber was almost completed at the time of cancellation. Congress allocated money to complete the fourth bomber and to continue flight tests of the four aircraft. Over 2,000 hours of flight tests were accomplished, proving the structural soundness of the craft and its engines. The avionic portions of the craft, however, had not been fully developed prior to the cancellation. As a result they were not fully tested in the B-1A.

³The strategic need for a new penetrating, manned bomber to replace the B-52s was questioned on two grounds: one disputed the mission, the other disputed which bomber to use. Some argued that a strategic, penetrating bomber mission had little utility, therefore supporting such a bomber was not cost-effective. The bomber would not arrive at the Soviet Union until after a devastating nuclear strike. Searching out the remaining enemy positions would be difficult and time-consuming, and have marginal value to the United States given that both countries had just experienced all-out nuclear attack. Given a growing defensive Soviet threat to bombers, the likelihood of survival of a bomber was thought by some to be minimal. The costs of developing and maintaining such a mission in peacetime were not deemed to be worth the marginal benefits derived after a nuclear attack when survivability is taken into account. Others thought that the role the bomber played was useful but could be accomplished by other means. Advances in technology since the conception of the nuclear weapon triad led some military observers to question the efficacy of a penetrating bomber. Enemy identification of bombers and countermeasures to bomber overflight progressed rapidly, increasing the likelihood that a bomber penetration mission, strategic or conventional, would fail. Meanwhile, cruise missile technology advanced apace. That might allow for completion of the current bomber mission but by using stand-off platforms for cruise missiles. In debates over the need for a new bomber, a strategic penetrating bomber was compared to its substitutes: existing B-52s equipped as stand-off platforms for conventional or strategic missions or intercontinental ballistic missiles (ICBMs) and submarine-launched missiles for solely strategic missions.

CHANGED DECISION ENVIRONMENT

Despite this decision, in the late 1970s and early 1980s the Air Force still advocated a new bomber.⁴ The Air Force held that the strategic penetrating mission was still central to the U.S. defense posture and that a manned, penetrating bomber was cost-effective compared with the other legs of the triad.

External Events That Shifted the Defense Environment

Several international events led to a pro-defense swing during the final years of the Carter administration. The disastrous attempt to rescue the hostages held in Iran left in doubt the United States position as a military power. Severe scrutiny was aimed at the military and its capability to carry out its defense missions. Equipment needs were subsequently reviewed to avoid future debacles. In addition, the Soviet Union invaded Afghanistan in December 1979, proving to many that this superpower was still bent on world domination and a real threat to United States interests. Military planners began to take more seriously the need for strategic missions.

In particular, military planners were concerned over a window of vulnerability in the U.S. defenses against the Soviet Union that would occur around 1985. The concern, discussed in the press and in military circles, was that a superior Soviet ICBM force that had been allowed to grow in the 1970s would soon be able to launch a preemptive attack against the United States, wiping out the land-based ICBMs. The aging B-52 bomber fleet would be unable to perform its mission against the improved Soviet defenses. Without an improved bomber, the United States would be forced to surrender rather than risk total annihilation in a second round of attacks.

The net result was that the political support for a new bomber program began to grow in reaction to these international events.

New Technology

One area of investment during the defense buildup of the late 1970s was a secret program to develop stealth technologies, which when integrated into the design of the aircraft would reduce the radar cross section of the plane so that it would be able to penetrate enemy air space without radar detection. In 1980 the stealth design concepts were developed enough so that an existing bomber, such as the F-111 or the B-1, could be modified and built in the early 1980s to be substantially more stealthy than the B-52.

⁴This history is based on the following sources: Holder, 1986; Kotz, 1988; Taylor, 1988; *Jane's World Aircraft*, Jane's Information Group, 1979-1988.

Alternatively, a fully stealthy advanced technology bomber (ATB) could be developed over a longer time period, incorporating still more stealth characteristics.

Suddenly, there were three potential bomber candidates instead of one: an interim bomber, either the FB-111 or a B-1, or an ATB.

Political Stances

Both political parties were anxious to appear strong on defense, and members looked to a new bomber as one signal to the outside world that American technical know-how and military superiority were still dominant. The issue of need for any bomber was pushed aside and the debate narrowed to one about which bomber to pursue.

Candidate Reagan, running on a strong defense platform, backed the building of an interim bomber. One oft repeated Republican criticism of Carter was that he had cancelled the B-1A program. The Republicans took the opposite view and supported an interim bomber program. The interim bomber was known as the Republican bomber and backed by Reagan, the Republicans, the House of Representatives, and Rockwell. President Carter, on the other hand, backed the advanced technology bomber. In the summer of 1980 several administration leaks to the press disclosed the ATB program, demonstrating Carter's support of the military and of an improved bomber. For those who had backed the cancellation of the B-1A program but were looking for something to prove their pro-defense stance, the ATB, or stealth bomber, became an alternative to the cancelled B-1A program. The ATB became known as the Democratic bomber, backed by Carter, the Democrats, the Senate, and Northrop, its potential builder.

Congressional Action

In 1980 Congress passed a law requiring a bomber and forcing a presidential review of options by March 1981, after the presidential election. The Defense Authorization Act of Fiscal Year 1981 required the Department of Defense to build a "multirole" bomber able to perform non-nuclear missions, serve as a cruise missile platform, and deliver nuclear weapons. The bomber was to have IOC no later than 1987. IOC was defined as 15 aircraft, or one squadron, deployed. Section 204 of the law specified that the Department of Defense review several candidates for the multirole bomber: the B-1A, a B-1 variant, an FB-111 variant, and the ATB. This congressional language reiterated the need for high-level attention to and urgency on the bomber question.

Election Results

Ronald Reagan was elected in November of 1980. The B-1B bomber, as part of the Republican campaign platform, appeared to be a certainty as Reagan and his advisors acted to substantially increase defense spending and develop a strategic modernization program. In addition, the Senate had a Republican majority that had backed the B-1B as part of their campaign platform. Finally, although the House remained Democratic, many members had adopted strong defense stances to gain reelection.

THE NEW BOMBER DEBATE

In November 1980 the Air Force began to argue for a limited number of each type of bomber.⁵

It began working during the lame-duck session on a proposal for the acquisition of two bombers. It split the 250 bombers (the previously stated requirements) into a proposal for 100 interim bombers to be immediately procured to meet the window of vulnerability in the 1985 to 1995 time frame and 132 stealth bombers for the 1990-plus time frame.⁶ Later, when the fully stealth bomber was built and deployed, the interim bomber could be made into a stand-off platform for launching cruise missiles.

Studies and Controversy

The question still remained which of the interim bomber options was best. The Air Force performed a Bomber Penetration Study to test different alternatives in flight. It contracted with the B-1A builders to design a modified B-1A and to test its penetration capabilities against Soviet defenses. The results were positive.

General Ellis, head of the Strategic Air Command, backed the FB-111. He thought that the FB-111, stretched and modified, would be less costly and more quickly available than the B-1B. The money saved could then be spent on the development of the ATB. In February 1981, Ellis made his position known in a Pentagon press conference.⁷ He argued against the B-1E bomber.

⁵Kotz, 1988, pp. 200-218.

⁶Kotz, 1988, p. 205. Kotz argues that this "requirement" for 100 interim bombers and 132 stealth bombers was based largely on political and economic factors. In past hearings the Air Force has stated that the bomber program would cost no more than \$20 billion. Rockwell had stated it could build 100 bombers for \$20 billion. The Senate, pro-ATB, wanted more ATBs than interim bombers. The Air Force proposed 100 interim bombers and 132 ATBs, which approximated its historical request for 250 bombers.

⁷John Flalka, "SAC General Says Work on B-1 Bomber Could Delay More Important Stealth," *Washington Star*, February 1981, p. 5.

General Lew Allen, chief of staff, backed the B-1B. It would be available shortly after the FB-111 and carry more weapons and cruise missiles. The latter were required by the congressional language. Kotz asserts that this requirement, inserted by congressmen from districts with strong economic interests in the B-1B alternative, automatically precluded the FB-111 from consideration because it could not carry cruise missiles.⁸

At the time, General Slay, then retiring head of the Air Force Systems Command, predicted that the congressional balance was for the B-1B.⁹ He urged the Air Force generals to bury their differences and come to closure on which bomber to back. The Air Force solidified. To new Secretary of Defense Caspar Weinberger, it advocated the building of two bombers: the B-1B and the ATB.

In March, the president's budget submission met the congressional deadline for a decision. It included \$2.5 billion dollars for the continued research and development (R&D) on the ATB and for initial funding for an interim bomber. But the administration did not specify which interim bomber would be chosen. Instead, the mandated Department of Defense Strategic Bomber Modernization Report, prepared by General Kelly Burke and submitted to the Congress in March 1981,¹⁰ outlined the rationale for the bomber programs and laid out the pros and cons of each bomber alternative without publicly specifying a preference.¹¹ Burke stated in a press conference that the bomber decision was deferred until contractors could provide better cost estimates.

Cost Issues

Cost had become a major concern. The FB-111 backers certainly emphasized this. But more important, Secretary of Defense Caspar Weinberger did not strongly support the idea of an interim bomber. This lack of strong support was based at least in part on cost considerations.¹² He had basically ruled out the FB-111 as the interim bomber and balked at the price of the two-bomber program. This program was estimated at approximately \$100 billion, a very hefty price tag. With a utility of only a few years before being replaced by the ATB, the interim bomber was not attractive. Like Carter, he backed waiting for the new stealth and making do

⁸Kotz, 1988, pp. 193-194.

⁹Richard Halloran, "Reagan Moving on Start of Fleet of New Bombers," *New York Times*, February 22, 1981, p. 1.

¹⁰Burke was deputy chief of staff for Research, Development, and Acquisition, U.S. Air Force, and had been a strong proponent of a new bomber program.

¹¹"Bomber Debate," *Defense Week*, March 28, 1981, p. 8.

¹²George Wilson, "Air Force Pressing Weinberger to Buy 2 New Bombers," *Washington Post*, March 25, 1981, p. 3. "A New Bomber May Take Off Soon," *Business Week*, May 25, 1981, pp. 160-164.

His concerns were strengthened by General Accounting Office (GAO) and Office of Management and Budget (OMB) documents that, in November 1980, reported that a 100 B-1B program would far exceed any Air Force estimates of cost. The Air Force had estimated the bomber program would cost \$20 billion in 1981 dollars. GAO and OMB countered that the program would cost far more—between \$30 and \$40 billion dollars when all aspects of the program were considered.¹³

This controversy over costs was not remedied by asking the potential contractors.¹⁴ During the summer of 1981 Weinberger requested estimates from the potential B-1B and ATB contractors, as well as Strategic Air Command (SAC). SAC analysts told the secretary that the cost of the B-1B would be \$27 billion in 1981 dollars, a price at which Congress would balk. Rockwell estimated the cost to be \$20.5 billion. Northrop leaders claimed that it could build the ATB by 1990 under a firm fixed-price contract! The head of Rockwell refused to bet his company on a \$20 billion firm fixed-price contract.

In the meantime, Congress held a series of hearings to clarify the position of the administration. Testimony by Richard DeLauer, under secretary of Defense for Research and Engineering, and Lieutenant General Kelly Burke did little to resolve the cost issue.¹⁵ They claimed the Air Force had firm price agreements negotiated among the B-1B contractors for 100 B-1Bs for \$19.7 billion in 1981 dollars. But when they were questioned further, it turned out that the contracts really covered only the first nine planes. The remaining contracts were still being negotiated. Further, the price tag did not include all the procurement costs, just as previously indicated by the GAO and Congressional Budget Office (CBO).¹⁶ In addition, these officials claimed that the costs were stable enough for firm fixed-price contracts.¹⁷ On the other hand, they testified that the avionics costs had doubled over the past few years as AIL developed a state-of-the-art defensive avionics system.

When Weinberger appeared to be heading toward a decision against the B-1B, the Air Force put pressure on Rockwell to commit to a \$20.5 billion price. Seeing the entire project about to be lost, Rockwell committed to the \$20.5 billion price but not specifics of the contract.¹⁸ This apparently satisfied Weinberger who then moved to the B-1B camp.

¹³George Wilson, "Cost of B-1Bs Estimated at \$39 Billion," *Washington Post*, November 10, 1981, p. 1. "Costs of 100 B-1Bs Figured at Double the Air Force Estimate," *New York Times*, November 10, 1981, p. A1.

¹⁴Kotz, pp. 207-211.

¹⁵Department of Defense Appropriations for 1982, *Hearings Before the Subcommittee of the Committee on Appropriations*, House of Representatives, Ninety-Seventh Congress, First Session, U.S. Government Printing Office, Washington, D.C., 1981, pp. 1081-1135.

¹⁶*Ibid.*, p. 1086.

¹⁷*Ibid.*, p. 1083.

¹⁸Kotz, 1988, pp. 210-211.

In July 1981 the Reagan administration stated that the ATB could not be pushed to completion in the 1980s without technological problems and cost overruns. The B-1B remained the most visible means of fulfilling campaign pledges to be strong on defense. In July 1981 Ronald Reagan personally made the decision to buy 100 B-1B bombers.

COST REDUCTION EFFORTS

The full decision on the strategic modernization program was to be announced to the public in October 1981. The administration had until that time to determine how to reduce the costs of the B-1B program from the \$27 billion appraisal that Congress would not accept to the \$20 billion that Rockwell had promised and Congress had been led to expect after several years of Air Force testimony.

A cost reduction plan was worked out by the Air Force and the Office of the Secretary of Defense (OSD). As part of the normal process of procuring a weapon system, an Independent Cost Analysis was performed by OSD. With support from the Air Force, OSD proposed several important cost measures for the program.

- Essential support equipment and spares would be removed from the program to be procured separately in the future.
- The Air Force would procure the bomber under a multiyear procurement contract requiring an up-front congressional commitment to Rockwell and the other contractors of a buy of 100 planes. This was assumed to save \$800 million in economic order quantities.
- The Air Force would act as the program integration manager to the four contractors involved, thereby not incurring the normal markup on all materials that passed through the prime contractor and saving 10 percent to 20 percent of the cost of the program.

OSD and the Air Force quickly translated these proposals into a plan to be approved by Congress. In October 1981, the president announced his strategic modernization program. By December both houses of Congress had approved funding for the B-1B program with three important conditions:

- The IOC date of 1987 remained in effect;
- A cap of \$20.5 billion in 1981 dollars was placed on the program;¹⁹ and

¹⁹See PL 97-114.

- The president had to guarantee personally in writing that the program would produce the bombers required to protect against the window of vulnerability by the IOC date and within the dollar cap.

This last unique condition was fulfilled by President Reagan, and the program began in earnest.

IMPLICATIONS

In the end, the high-level actors approved the program as part of a political negotiation, rather than as part of the technical/analytic process postulated in defense acquisition regulations and carried on by lower-level career acquisition experts. Political support was based on the coalescence of a perceived increase in threat, the election of a president who backed the program, a fortuitous budget outlook, and strong interest groups advocating each of the two bomber programs. The agreement satisfied the major actors in terms of both benefits and costs. On the benefit side, the Air Force was satisfied that it had a firm commitment to an interim bomber and a potential commitment to a future stealth bomber. Political actors were satisfied that they had made a strong pro-defense statement that they felt was required to ensure constituent support. Both groups of contractors, Northrop for the ATB and Rockwell for the B-1B, were satisfied with the prospect of large government contracts.

The high-level actors imposed a series of constraints. These satisfied some of the concerns of the actors involved. The early IOC date satisfied those concerned with meeting the perceived Soviet threat. The funding cap assuaged Congress's concerns about budget and past B-1A cost growth. The multiyear arrangement and the Air Force acting as program manager enabled some to argue that cost would be kept to a minimum and that cost-effectiveness would result. The president's own pledge assured some that the program would continue to have high-level review.

But as much as this arrangement satisfied many concerns, it laid the groundwork for the increased risks that the program would not perform as expected. These possible risks are described in the next section.

3. POSSIBLE IMPLICATIONS OF THE B-1B PROGRAM STRUCTURE FOR RISK MANAGEMENT

The decision to build the B-1B was made at the highest level of government. It was a joint decision by Congress and the president, supported by the highest levels of the Air Force. The constraints set by these levels at this time were straightforward and appropriate for a program based on well-developed, mature technology. This section reviews those constraints and their implications for risk management without delving into the technical risks in the program.

SOLE SOURCE CONTRACTING

The urgency of the requirement to meet the threat implied that an existing aircraft be modified. A new development was not possible—that was the role of the stealth craft, which would not be available for ten years. This meant that the contract would be awarded to the existing B-1 contractors: Rockwell, GE, Boeing, and AIL. No competition was considered, as this would take up more time. Everyone at the highest levels accepted the notion that the award would be sole source. If the original B-1A team was going to be the B-1B developers, then, logically to save time, the original team would automatically get a sole source contract for the B-1B production.

Sole source arrangements, while sometimes appropriate, had been increasingly frowned upon by Congress and the administration. In fact the Reagan administration had campaigned on a platform of bringing private-sector practices, especially competition, into the government.

Arguments for design and prototype competition had two risk-related themes. First, competition in design and early prototyping provided the client with multiple designs and proven prototypes. As a technical risk reduction technique, this can be compared to a hedging strategy, where if one technology does not pan out, another can be easily substituted. Second, competition at both phases would ensure the contractor presented the lowest-cost alternatives to the client. The competitive contractors would work to reduce their costs to underbid each other. Furthermore, both contractors would have worked through the technical problems during prototyping, ensuring that they were well qualified technically. The Air Force would then be in a position to choose the most qualified and lowest-cost contractor. The contractor would have demonstrated some technical competence and would have made a bid knowing a competitor was also bidding, thus constraining the price.

It could be argued that the prototype competition had taken place—between the FB-111 and the B-1B. But, in fact, a physical prototype of neither existed. The modified B-1A used in flight tests did not have the avionics suites envisioned for the B-1B and did not incorporate the structural changes proposed, especially gross weight increase. The same was true for the "stretched" FB-111. Thus, a single design was accepted without a physical "fly-off" between actual competitive prototypes. Most important, the necessary technical advances to the aircraft, essential to make it survivable and improve its capability over that of the B-52, especially the defensive avionics, had not been prototyped.

Although not highlighted at the time, this arrangement was more risky than a normal sole source contract because of the experience base of the different contractors involved. Certainly, Rockwell, Boeing, and GE had substantial background in their respective areas and had proven track records. However, AIL's experience was more limited. It was primarily a development company and had much less experience in large-scale production.

CONCURRENCY

The urgency of the requirement imposed concurrency on the program. Concurrency means making production decisions prior to the completion of FSD (full-scale development) and testing. Within the time frame imposed by Congress and the window of vulnerability, production would have to overlap FSD. Full-scale development and production completely overlapped to the extent that contracts covering them were signed on the same day.

Concurrency can impose cost, schedule, and performance risks on a technical development, that is, increase the probability of poor outcomes. In concurrent programs, the testing of the article is not completed before production decisions are made. Any technical flaws found during testing must be remedied in future production as well as in past production articles. This retrofitting can be very costly in time and money, especially if tooling changes are required. When faced with these costs, decisionmakers often opt for reduced performance rather than a retrofit and production line change. This is appropriate as long as the reduced performance does not too severely affect the operational capability of the aircraft to perform its mission. The key issue, then, is whether the program has probable technical difficulties that will become more apparent in a test program. For mature programs, where the technology is well in hand, this is less probable, and concurrency does not impose as great a risk. This is also true for programs that have alternative designs that can be substituted if one technology development does not proceed as expected. For more technically immature programs with a single design path, the probability and severity of negative outcomes are greater.

On the other hand, completely sequential scheduling has its own costs. Producer's facilities might sit idle, and urgent mission requirements might not be met.

Concurrency has been the subject of much debate in the defense acquisition world.¹ Some early experiences with it produced excellent results, such as those of the early ballistic missile programs. Later efforts, such as with the cruise missile, C-5A, and Divad programs, showed less favorable outcomes. In general, the military has advocated concurrency based on the urgency of the threat, while Congress has showed some concerns at the associated problems of cost growth and diminished performance.

The Department of Defense and Air Force support for concurrency had waxed and waned over the years. After the C-5A program under Secretary of Defense Robert McNamara, concurrency was discouraged. Review of several procurements showed it to be the cause of many problems. The Nixon administration instituted a "fly-before-buy" policy, requiring prototyping and substantial testing before a production decision. David Packard was the main proponent of this approach. However, in March 1978, a Defense Science Board (DSB) study found that DoD had gone to excessive lengths to avoid concurrency, indicating concurrency should depend on the urgency and the technical risk of the program.² The task force recommended several changes to DoD Directive 5000.1 that would encourage more concurrency.

The Reagan administration encouraged concurrency to combat the perceived urgent threat from the Soviet Union. Significantly, General Lawrence Skantze, deputy chief of staff for Systems, Air Force Systems Command, sat on the DSB task force. In 1979 he became commander of the Aeronautical Systems Division at Wright Patterson AFB. In 1982 he was named deputy chief of staff for Research, Development, and Acquisition, U.S. Air Force. It was during his tenure in office that concurrent development was proposed for the air-launched cruise missile, the AMRAAM missile, the LANTIRN, and the B-1B aircraft.

The concurrency imposed on the B-1B program was large, but concurrency can work under the following conditions, most of which were not met in the program. Some of these conditions apply to any program, but more so for concurrent ones.

- The program has low technical risk. Although this was argued to be the case for the B-1B, in fact it was not. This issue is covered in the next section.

¹This discussion is based on information from Wayne Foote, *Master's Thesis, History of Concurrency: The Controversy of Military Acquisition Program. Schedule Compression*, Air Force Institute of Technology, Air Force University, Wright Patterson Air Force Base (AFB), OH, 1986.

²Defense Science Board, *Report of the Acquisition Cycle Task Force*, Washington, D.C., March 15, 1978.

- The program is militarily urgent and thus has high-level support to push it through the bureaucratic mazes of the organization and reduce, by high-level exemption, the associated red tape that could slow down the concurrent schedule. Initially this appeared to be the case for the B-1B. Later, as the Soviet threat diminished and the problems associated with the program became evident, its urgency was reduced.
- Highly skilled and qualified personnel lead the effort, reducing the probability of negative effects, especially schedule slips, associated with poor management. This might have been the case for the B-1B contractors, but the government had chosen to act as the integrator, a job it had not performed in the past and for which Air Force personnel were not experienced.
- The program has extensive autonomy. Initially, both Congress and OSD took a hands-off approach to the program, avoiding micromanagement. However, this was given at a price. The program was controlled by use of a tight cost cap. This significantly reduced the Air Force's flexibility to manage the program. Alternatives such as technology hedging strategies at the component level were not practical under these conditions.

Thus, the program lacked the conditions that can increase successful programmatic outcomes under concurrency.

COST CONSTRAINTS AND CONTRACTUAL FORM

The cost cap increased the probability of poor outcomes as well. This cap was imposed prior to actual FSD or Low-Rate Initial Production (LRIP) before any firm cost information had been obtained. The past acquisition record showed cost growth in sophisticated weapon programs, and concurrency made that growth more likely. Furthermore, the B-1A program had been experiencing substantial cost growth prior to its cancellation. An informed observer would project that cost growth would be likely in a technically risky program, as the B-1B was when compared with the B-1A.

The risk here was that the Air Force would not be able to acquire the system it wanted for the price dictated by the political agreement. The potential problem was not just inefficiency in the allocation of resources but possible loss of credibility in other acquisition activity. The Air Force had committed to the cap, assuring Congress that the program was doable. To fail to meet the cap would open the way for recriminations, putting other Air Force programs in possible jeopardy.

The cost cap might substantially increase the probability of negative outcomes for the contractors. Because of technical risk, most FSD contracts use cost-based, not fixed-price, arrangements. In the event of technical problems that can be resolved only with further spending, contractors under fixed-price contracts are at risk of losing profits, or worse, of incurring costs greater than revenues, forcing other activities or shareholders to subsidize the fixed-price contracts. However, Rockwell, to meet congressional approval, had agreed to a fixed-price contract. And application of a cap implied such arrangements for the other contractors.

The administration proposal called for the use of a multiyear contract. This ensured that the contractors faced a reduced probability of program cancellation, a very real concern at the time. Other programs must justify themselves on a yearly basis and are subject to budget swings that can impose additional costs on the program. For the B-1B, the contractual arrangements held the promise of program stability and helped assure both the Air Force and the contractors that congressionally instigated budget cuts would be minimized.

However, multiyear arrangements can result in some costs of their own. First, the government, by committing its funds, reduces its flexibility in dealing with contingencies. Second, the multiyear contracts can impose costs on the government if the technology is not mature. Technical difficulties on multiyear programs can result in large commitments for systems that do not produce the desired operational capability. The GAO does not recommend multiyear contracts for any program until after a full rate production run has proven the program elements to be stable.³ Both the above sets of costs can be reduced if the service does not commit to the multiyear until the technology is proven.

INTEGRATION ROLE

In most contractual arrangements for aircraft, the airframe manufacturer also acts as the aircraft integrator. It is the prime or only contractor to the government. Other contractors are under contract to the prime and hold no contractual relationship with the government. Any problems with subcontractors are handled by the prime, and the prime accepts the responsibility for the integration and warranty of the aircraft. The prime uses its own strict contractual arrangements, especially warranties, and oversight of its contractors to ensure that it is not negatively affected if any difficulties occur. For accepting this responsibility and performing the extensive management function, the prime usually charges

³General Accounting Office, *Analysis of DoD's Fiscal Year 1985 Multiyear Procurement Candidates*, GAO/NSIAD-85-9, Washington, D.C., October 25, 1984.

a fee on all subcontractor materials delivered. The government accepts this cost, rather than performing the oversight and management functions itself.

For the B-1B program, the government was to act as the integration manager, a position it seldom held.⁴ Rockwell, the airframe manufacturer, did not act as the contractually responsible integrator of the entire weapon system, as is normally the case. Instead, the government had four primes: Rockwell, Boeing, AIL, and GE. Moreover, it had separate contractual agreements with each. Rockwell did the physical integration of the aircraft, but the Air Force was responsible for integration management decisions.

The government, then, accepted a major risk management function—that of integration management. Three possible risks were associated with this function, which had the possible reward of reduced costs. First, the assumption, as discussed above, was that this arrangement could avoid the fees charged by the prime contractor. However, assuming that the prime is not simply overcharging the government for the management of integration, some real costs are associated with this function. These were not included in the program costs, thus putting more strain on the program budget and increasing the probability of cost overruns. Second, the Air Force personnel had little experience with this management function, and this lack of experience or not allotting the number of personnel needed for the additional workload could increase the probability of negative outcomes. Finally, accepting this role put the Air Force SPO in the position of a partner with the other contractors. This possibly jeopardized the Air Force role of contract oversight.

IMPLICATIONS

The unique circumstances occurring in 1981 led to the approval of the B-1B program but also placed specific constraints on its management. The program strategy, normally developed by an SPO after careful consideration of the technical aspects of the program, was determined by higher levels of government in a negotiated settlement.

The combination of different attributes of this program strategy was unique. Other programs had had concurrency, but few had that much concurrency. Few, if any, had ever had congressionally imposed caps or IOC dates. Certainly the combination of a budget cap and concurrency was unusual. The congressional and administrative support of a sole source contract was also unusual, as was the government's acting as the integration manager. Taken all together, this was a highly unusual plan.

This management plan, or series of constraints, appeared at the time to have some value. It was intended to reduce the possibility of cost overruns and to ensure an operating

⁴It has held this role on the MX missile program and on the Global Positioning System.

capability when needed. More important, it was the best deal that could be struck by the different parties at the time.

Even at the time of its formulation, an informed observer could have been aware of some of the risks involved—risks that had manifested themselves on other programs with one or two of these characteristics and had resulted in program difficulties. Concurrency was known to impose additional risks on programs. Sole source contracting was thought to have some detrimental effects. Prototyping and competitive designs had been advocated in the past to reduce risk but were ruled out in the B-1B strategy. Certainly the government's integration management function presented new management challenges added to an already challenging strategy. Putting them all together in one program increased the probability of negative outcomes while it decreased the ability of SPO management to adapt to surprises.

However, in testimony these obvious potential outcomes were not emphasized. Perhaps the possibility of technical risks was not viewed as important in this environment where high-level actors sought an agreement that could immediately show U.S. resolve in the face of military challenges. These were the immediate rewards that were sought and were thought to be gained by the strategy invoked. The downside, long-term increase in the probability of cost overruns and not meeting the threat, was thought controlled by Congress through the budget cap and the firm IOC date. These constraints were examined in a positive light without reflection on the additional costs they might pose. The idea that the bomber would have technical difficulties that caused a shortfall in performance did not enter into the calculus.

4. TECHNICAL ADVANCES AND THE MANAGEMENT PLAN

From a political viewpoint, the program strategy was certainly valid. However, the strategy was valid from a technical viewpoint if, and only if, the B-1B program was based on a fully mature technology base. Even under this condition of full technical maturity, the strategy would be challenging, allowing for few of the inevitable mistakes made in the acquisition process. As it turned out, the technology was not mature.

But the program strategy has to be judged based on the information available at the time it was developed. The data sources available on technical aspects of the aircraft dating to the program's initiation are somewhat inconsistent. In one sentence they describe the B-1B as being a simple modification of the B-1A, with "most subsystems . . . successfully deployed on a previous system."¹ This would indicate that few development issues remained and that the technical risk was primarily in integration of different components and subsystems. However, integration tasks, even without other technical challenges, can be considered as incorporating high risk. The sources then describe the all "new" or "greatly improved" offensive and defensive avionics systems and major structural changes to the aircraft. These imply that significant development remained to be accomplished, increasing the technical risk.

This section examines the technical advances incorporated into the new aircraft as of 1982, the first full year of the program, and concludes that the management strategy was probably inappropriate, given the known technical issues.

PROPOSED CAPABILITY

The mission scenario of the B-1A, the predecessor to the B-1B, was to penetrate Soviet airspace at supersonic speed. It was then to approach the target at below sonic speeds at altitudes of around 500 feet. It was to have quick takeoff capability and have one-tenth the radar cross section (RCS) of a B-52.

The mission profile of the new B-1B was different. It was, like the B-1A, to have quick takeoff capability. But it would approach its targets at lower speeds and closer to the ground than the B-1A. Its RCS of one-hundredth that of the B-52 made it more stealthy. This and improved offensive and defensive avionics would allow it to penetrate the enemy's territory, despite more sophisticated Soviet air defenses. This latter attribute was a key requirement

¹Aeronautical Systems Division, B-1B System Program Office, "B-1B Test and Evaluation Plan," April 15, 1982, p. 4.

for operational capability. While the reduced cross section would allow it to come close to its targets, the defensive avionics were necessary for survival to the point where the bomber could launch its weapons. Without stealth and the ability to evade the better Soviet defenses, the B-1B would be little better than the existing B-52s.

The two aircrafts' characteristics are compared in Table 1, which shows the seemingly minor differences between them.

Table 1
B-1A and B-1B Characteristics

	B-1A	B-1B
Dimensions		
Max. gross weight	395,000 lbs	477,000 lbs
Max. payload weight	115,000 lbs	134,000 lbs
Max. fuel load	NA	195,000 lbs
Length	150 ft	147 ft
Wing span (full)	136 ft 8 in	136 ft 8 in
Wing angle		
Min.	15 degrees	15 degrees
Max.	67 degrees	67 degrees
Performance		
High altitude	50,000 ft	50,000 ft
Low altitude	500 ft	200 ft
Max. speed high altitude	2.2 mach	1.25 mach
Max. speed low altitude	750 mph	600 mph
Unrefueled range	6,100 miles	7,455 miles
RCS	1/10 B-52	1/100 B-52

SOURCES: B-1A: *Jane's All The World's Aircraft, 1981-82*, pp. 453-454; B-1B: *Jane's All The World's Aircraft, 1982-83*, pp. 463-464.

NA: not applicable.

REQUIRED DESIGN CHANGES

However, to accomplish these changes and counteract the Soviet defenses effectively, substantial changes had to be made to the internal structure and avionics of the aircraft. In addition, the flight tests on the B-1As had uncovered several problems that required remedies.

Aircraft Structure

The airframe was described in congressional testimony as being 80 percent in common with that of the B-1A, and those testifying emphasized that the B-1A had undergone thousands of hours of test flights.² However, the B-1B was expected to fly lower, have a

²Department of Defense Appropriations for 1982, 1981, pp. 1093 and 1122.

longer range, carry more weapons, and be stealthy. Later, as the ATB came on line, the B-1B had to convert to a cruise missile platform for standoff missions. These lifetime mission requirements necessitated structural redesign of the aircraft to accommodate the increased weight, reduce the turbulent ride experienced at low altitudes, and reduce the RCS. Several design changes from the B-1A were needed: landing gear, tires, wheels and brakes capable of carrying a heavier load, structural reinforcement within the craft, a movable bulkhead to accommodate the air-launched cruise missiles, fuel tanks in two weapons bays and under the fuselage, and hardpoints added for external missiles and fuel tanks.

New materials were planned to be incorporated to provide greater strength with less weight. Composites were to be put into the bomb bay doors, flaps, structural mode control system, and wings. The major airframe piece, the carrythrough structure, was to be produced using a new process called diffusion bonding.

In addition, flight tests of the B-1A had identified several problems that had never been resolved and had to be remedied on the B-1B. These were hinge movement limitations in the swept wing under certain flight conditions, roll control problems associated with the nonlinear gearing, drag associated with poorly sealed overwing fairings, problems with composite materials, flap/slat system modification, and problems with the weapons bay doors vibration. The B-1A had been subject to extensive fuel leaks and false alarms in the central integrated test system (CITS).

Engine Design

The engine design contained few changes compared with that of the B-1A. The B-1A had used four YF101-GE-100 engines. These had been extensively tested in the B-1A program. This program showed some modifications were in order. The engine air turbine starter and cross bleed had to be modified because engine restarts had taken longer than expected in some areas of the flight envelope. Engine nozzle damage occurred at the trailing edge between the two engines, caused by too turbulent an environment at the nacelles. Most of these problems appeared in low-level flight—a fact that threatened the ability of the aircraft to perform its mission.

The mission for the B-1B required a decreased RCS. This demanded that the engine inlet be redesigned using absorbent materials in the vanes of the power plant.

Altogether these combined into a modified engine designated as the YF101-GE-102.

Offensive Avionics

The offensive avionics were meant to generate data for navigation, penetration, weapon delivery, and air refueling. The offensive avionics included an automatic terrain-following capability for night and all weather conditions.

The offensive avionics for the B-1B were 75 percent in common with the B-52's.³ This system was in fact a series of boxes that had been tested on the B-52s and on the B-1A. However, improvements in these existing offensive avionics were planned to include three subsystems: a new forward-looking radar, an improved automatic terrain-following radar (ATFR), and an inertial navigation system (INS).

A forward-looking radar, the APG-66, had been developed on the F-16 by Westinghouse. The Air Force stated that the B-1B system would have 50 percent to 70 percent commonality with the F-16 system.⁴ The existing APG-66 system was undergoing a major redesign, called the APG-68, as part of the Multinational Staged Improvement Program (MSIP) associated with the F-16. The major change of the APG-68 over the APG-66 was the incorporation into one unit of all the digital processing activities. The APG-68 program was having difficulties at this time.

The B-1B also called for an improvement in ATFR, the Westinghouse AN/APQ-164. This was to be derived from improvements in the AN/APG-66 as well and would use a low-observable phased-array radar for low-altitude terrain following.

The inertial navigation system was to be developed by Singer-Kearfott based on one developed for the F-16 program.

Defensive Avionics

The system was intended to counter surface-to-air-missile, anti-aircraft, and air-to-air-missile radars and to degrade by jamming early warning and ground control radars. Significantly, it was supposed to jam many different radars simultaneously. To do so, it had to detect and analyze threat signals, identify threat, select a countermeasure, and deny the location of the aircraft to the enemy by use of active electronic jamming. This complex system contained several different components. A forward-looking radar warning receiver (RWR) that included antennas and direction-finding receivers would pick up threat signals. A tail warning function (TWF) would pick up threat signals from the rear. A processing unit, jamming unit, and antennas would select an appropriate countermeasure and actively send

³Department of Defense Appropriations for 1982, 1981, p. 1120.

⁴B-1B SPO, Briefing: B-1B, July 1, 1981. In hearings before the Subcommittee on Appropriations, DoD representatives stated that the offensive avionics were 75 percent in common with those on the B-52s (p. 1120).

out electronic countermeasures to jam the incoming radar. Chaff and flare ejectors could also be used to confuse incoming enemy weapons.

The ALQ-153 tail warning function made by Westinghouse and incorporated into the defensive avionics was common with the B-52. This system had performed well and was in production for the B-52 at the time of the B-1B decision, with some improvements planned. The chaff and flare ejectors were also well understood.

The radar warning receivers, the processing units, and jammers were all part of a unit called the ALQ-161 made by AIL/Eaton. At the time of the B-1A program cancellation it had not been sufficiently developed for testing. Thus, its performance capability was unknown. Furthermore, improvements were to be made to the existing system. The B-1A system had 88 different components; the B-1B was to have about 120 different black boxes. The B-1B system was to detect an additional band of radar, band 8, and integrate the tail warning function into its software equations. The Air Force recognized it as a system still under development.

Assessments

In testimony before Congress and in briefings, the Air Force said the development had low technical risk. The degree of commonality with the B-1A (and the fact that the B-1B was a modification of it) argued that the extensive data from the B-1A test program lowered the risk. In the Acquisition Plan for the program, it again rated the program as having low technical risk.⁵

On the other hand, the Air Force promoted the advances that the B-1B would make over the B-1A and the state-of-the-art equipment that would be incorporated. The Test and Evaluation Master Plan laid out the past technical difficulties associated with the B-1A program.⁶ It discussed the extensive amount of testing needed to prove the B-1B to be mission-capable and emphasized that possible technical difficulties in some untested subsystems could reduce the mission-capability of the program.

Despite the low-risk assessment of the Air Force, the program did indeed have technical risks, especially in areas that could threaten its operational capability. These risks were evident at the time of the decision to commit to the B-1B.

⁵B-1B SPO, USAF, "Acquisition Plan," Number 81-1-1020.

⁶Aeronautical Systems Division, B-1B System Program Office.

- The advances in the program would not be possible without some associated technical risk. Each improvement involved technical advances that were not proven.
- The modifications and improvements were in areas that were important in meeting the mission requirements. Failure to make required technical advances would cripple the mission-capability of the aircraft. For example, without the automatic terrain-following capability, the craft could not perform its low-level flight profile. Without its tail warning function or active jamming capability, it would be subject to attacks that would render it unable to perform the mission. Thus, while the soundness of the structure of the aircraft was proven in flight tests, the components that made it survivable and able to perform its mission were largely unproven.
- Many of these subsystems had been used before on other aircraft, but they had not been used on this craft or used together in this particular configuration. The integration of these many systems added technical risk to the program.
- Review of the B-1A tests revealed important remaining technical problems, indicating the baseline aircraft had technical risks associated with it.

TECHNICAL RISK AND OTHER PROGRAM CONSTRAINTS

Despite these technical risks, the B-1B program proceeded with complete concurrency, inducing further risks. First, the flight-test plan was optimistic. It had no time allotted for fixing technical problems that inevitably show up in tests. Second, important flight tests on the defensive and offensive avionics were not scheduled until after significant production. The test plan called for B-1A numbers 2 and 4 to be modified to begin flight-testing in April 1983 and July 1984, respectively. The first true B-1B would not be produced until December 1984 and would not be ready for testing until March 1985. The IOC date for 15 operational aircraft was June 1986. The defensive and offensive avionics were not scheduled for even initial flight tests until July 1984, and then only on the reconfigured B-1A, number 4.⁷ By that time production of over 18 aircraft would have begun, without flight tests of components known to require further development and known to be very important to the survival of the aircraft in its mission profile.

⁷Deputy for B-1B, "B-1B Program Management Plan," Aeronautical Systems Division, Wright Patterson AFB, OH, June 1982, p. 12. Clarence Geiger et al., *History of the Aeronautical Systems Division*, Vol. I—Narrative, October 1982–December 1983, p. 153.

In a highly concurrent program, especially one with a funding cap, this management approach added risks. Any technical difficulties, which were very likely in a program of this size and complexity, would necessarily result in expensive retrofits, retooling the production line, and schedule slips. The result would be not only cost overruns and schedule delays, but also acrimonious investigations by Congress.

5. CONTRACTUAL STRUCTURE

Risks undertaken by the Air Force do not necessarily translate into risks undertaken by the contractors. In fact, in the case of the B-1B, innovative contractual arrangements protected the contractors from many potential risks while still meeting the strictures of a funding cap. These agreements, reached early in the program, indicate both the government and the contractor were aware of the risks involved in the management plan for the B-1B and the technical risks inherent in the design.

ALLOCATING RISK THROUGH CONTRACTS

In general, contractual arrangements do not impose further risk upon a program, nor do they remove risk. Instead, they allocate the existing risk between the parties to the contract. In the case of government contracting, the government is usually the least risk-averse party—willing to accept more contractual risk to accomplish its goals. Contractors are more risk averse because they have fewer resources to call upon in case of program difficulties.

The above implies that contractual arrangements can be used as indicators of where risk lies in a program. Risk usually lies in three general areas. First, the possibility of unplanned high-level government actions imposes risk on the program. Lower budgets than expected, program cancellation, or changes to requirements might make some part of the contractors' efforts unproductive. If the contractors or government has invested large sums of nonreimbursable money into equipment to produce a particular design, any changes to requirements can impose financial costs. Second, there can be technical risk in a program. This risk is increased the more the program incorporates technical advances or requires never before accomplished integrations. It is also potentially increased if a program requires commitment to production prior to ironing out all the technical difficulties or before the design becomes stable. In the event that the product does not perform as expected or the design is evolving, the contractor might be required by the contract to do extensive retrofits at its own expense. Third, there is risk of the effect of inflation on program costs. The contractor can face financial loss if these costs increase beyond the estimates it had made.

In negotiations, the parties will assess and allocate the risks in the program. Contractual arrangements, such as the contract type, the cost and price arrangements, and the special contractual terms, are used to allocate these risks. The more these arrangements push risk on the government, the more evident it is that the estimated risk was too

burdensome for the contractor to undertake. Significantly, these arrangements also show what risks the parties were most concerned about. Finally, the progression of contract type can indicate the degree of risk involved as well. If contracts evolve from a cost-based toward a firm fixed-price contract without intervening steps, one can conclude that the parties assessed little risk left in the program at the time the fixed-price contracts were signed. In highly risky environments, the contracts progress slowly, with provision for contract review to protect both parties from being tied into extremely unsatisfactory situations.

The following are rules of thumb that a rational contractor would use to protect its interest in a risky environment.

- Progress from a cost-based contract to a fixed-price incentive, to a firm fixed-price contract only as technical and cost risks recede.
- Use a shareline on fixed-price incentive contracts that impose the least risk of cost overruns on the contractor, say 50/10 as opposed to 60/40, when technical or cost uncertainty exists.
- Use warranty clauses that limit contractor responsibility through time, dollar, or specification limits when technical risk exists.
- Use Engineering Change Proposals (ECP) clauses that allow for cost renegotiation when technical risk is high.
- Use extensive Economic Price Adjustment (EPA) clauses when the economic outlook is uncertain or when the funding outlook appears to indicate program stretch-outs.
- Use generous indemnification, cancellation, and termination clauses when requirements and budgets appear unstable.

CONTRACT TYPE AND PROGRESSION

The B-1B contract type varied little from contractor to contractor, as shown in Table 2. All the contractors started with fixed-price incentive contracts. This indicates low risk in the development phase, as cost-based contracts would have been more acceptable if technical and cost risks had been high.

Table 2
Progression of B-1B Contract Types

	Rockwell	Boeing	AIL	GE
FSD	FPI(F)*	FPI(F)	FPI(F)	FPI(F)
LRIP	FPI(F)	FPI(F)	FPI(F)	FPI(F)
ANNUAL PRODUCTION	None	None	None	None
MULTIYEAR	FPI(F)	FPI(F)	FPI(F)	FFP**

*FPI(F) = fixed-price incentive (firm), meaning the price has been firmly set at the signing of the contract.

**FFP = firm fixed price.

However, in a normal development one would expect these contracts to progress to firm fixed-price form during production. In the Rockwell, Boeing, and Eaton contracts they did not, confirming that cost risk, whether from technical or other sources, remained in the program. The GE program, however, did go to a firm fixed-price contract during the multiyear procurement, indicating low-cost risk and a stable technology.

Part of the explanation for this lack of progression is straightforward. The normal progression would be to complete a significant portion of FSD to establish a design and firm cost before committing to production contracts. But with complete concurrency in the program, this conservative approach was not possible. Instead, each of the three contractors committed to both FSD and LRIP contracts simultaneously. GE signed initial FSD and FSD contracts in February 1981 and LRIP contracts in April 1981. The other three contractors had signed very low-level initial FSD contracts in October 1981 with the congressional appropriation and the president's message. But the program really got started with the full FSD contracts. Rockwell signed both FSD and LRIP contracts on the same day in January 1982. Boeing and AIL signed their FSD and LRIP contracts in June 1982. Prior to any substantial production, and certainly before a completed annual production run, the contractors also signed up to a multiyear procurement contract. This arrangement was approved by Congress in December 1983 and begun in 1984. It covered 88 of the 100 aircraft.

This contractual overlap, due to concurrency, would impose certain cost and design risks on the contractors. The design and cost would remain untested and unproven when the production contracts were signed. The contractors would be reluctant to commit the firm to a fixed-price production contract when the technology was still immature in a potentially unstable situation. Thus, except for GE, the contractors protected themselves with fixed-price incentive contracts rather than firm fixed-price contracts. GE, on the other hand, had

done substantial testing under the B-1A contracts. Less uncertainty remained, allowing a firm fixed-price contract in the multiyear.

COST AND PRICE ARRANGEMENTS

The risk allocation in these contracts was further modified by the cost and price arrangements. These arrangements tended to reduce the risk born by the contractors and placed the burden on the government.

All four contractors used fixed target costs as opposed to sequential cost fixing. This means that they agreed at the time the contract was signed to a particular cost structure. Alternatively they could have refused this and chosen a specific date upon which to fix the costs based on further available information. The fact that fixed targets were chosen indicates some confidence about costs by both parties.

Additional indicators come from the percentage difference between the target cost and the ceiling set in the contract, as shown in Table 3. The less the percentage difference, the less the cost risk perceived by both parties. Except for the GE contract and the Boeing multiyear contract, the percentage difference between target and ceilings was set close to the maximum allowable by regulation. This indicates some concern on the part of the three contractors and the government that costs were still quite uncertain, even on the multiyear contract. But again, the multiyear was signed very early in the program prior to the benefit of stable cost estimates.

The sharelines also indicate remaining risk. For example, Rockwell accepted only 20 percent of the costs of any overruns between the target and the ceiling. Boeing and AIL had about the same arrangements, while GE's were different. It accepted a much larger allocation of the risk during FSD, indicating the risks were perhaps small.

No target fee data are available, except for the multiyear. This shows close to the maximum fee allowable and is again an indication that the contractors had to be well compensated to undertake this risk.

SPECIAL CLAUSES

The special clauses show remaining concern about technical, requirements, and cost risks, as shown in Table 4. The contracts included extensive EPA and ECP clauses to cover different contingencies into the multiyear phase of production. This indicates that many uncertainties associated with design changes and cost fluctuations remained.

Table 3
Contractual Arrangements

	Rockwell	Boeing	AIL	GE
FSD				
Ceiling percentage		133	133	118.75
Shareline				
over	80/20	75/25	80/20	50/50
under	80/20	50/50	80/20	50/50
Profit percentage	NA	NA	NA	NA
LRIP				
Ceiling percentage	135	133	134	118.95
Shareline				
over	80/20	75/25	80/20	70/30
under	80/20	50/50	80/20	70/30
Profit percentage	NA	NA	NA	NA
MULTIYEAR				
Ceiling percentage	135	123	134	NA
Shareline				
over	80/20	75/25	80/20	NA
under	50/50	50/50	80/20	NA
Profit percentage	14.2	13.5	14.0	NA

NA: not applicable.

In addition, Rockwell appeared to be concerned about program cancellation during the multiyear phase. Thus, its contract included indemnification clauses in case of government cancellation or stretch-outs. Interviews with the airframe manufacturer indicated that it had made large investments in capital and facilities. Cancellation would impose a high, short-term cost on the firm. Thus, the contract protected against it with indemnification clauses.

Table 4
Contract Clauses

	Rockwell	Boeing	AIL	GE
EPA	Yes	Yes	Yes	Yes
ECP	Yes	Yes	Yes	Yes
Indemnification	Yes	No	No	No
Warranty				
Time limit	6 months	6 months	6 months	7 years
\$ limit	Yes	No	Yes	Yes
Delayed specification	Yes	Yes	No	No

Finally, contractors provide strong warranties when the technology and costs are certain and weak ones when they are not. FSD contracts require no warranties, but production contracts do. Further, all contractors are required to warrant material and workmanship, and the B-1B program offered no exception. Terms of the warranties did differ.

Among the B-1B contractors, GE provided strong warranty clauses, including a seven-year time frame for warranties and no delayed specification of the warranted performance. On the other hand, the other three contractors warranted their products for only six months. Rockwell and Boeing further reduced their risk by requiring that the performance specified in the warranty be delayed until after more testing. All subsequent items produced would meet this performance, but not any produced prior to the specification. They agreed to cover only the performances actually achieved during specified tests well in the future. They refused to cover expected but as yet unproven performances. Finally, Rockwell, AIL, and GE further limited their warranty by use of a cap, specifying that warranty costs could not exceed a prespecified amount and that the government would have to pay for all mandated retrofits above the agreed-to amounts.

This is in sharp contrast to a more normal defense industry warranty that covers a prespecified level of performance for all items produced, and this performance is specified at the beginning of the contract.

IMPLICATIONS

The contractual language clarified that the government and contractor were cognizant of the risks in the program very early on.

- The contractors and the government recognized technical and cost risks in the program.
- The contracts did not penalize the contractors for performance shortfalls. Warranty language minimized the contractor penalties; the burden of performance shortfalls fell on the government.
- Except for the GE contracts, the contracts minimally penalized the contractors for cost overruns. Ceilings on fixed-price incentive contracts were set high, and the sharelines specified passed a large portion of the burden of overruns onto the government.
- The contractors' reward for undertaking program risk was the potential for a long production run. This potential reward was protected by the use of a multiyear and the early commitment to production and multiyear contracts.

6. DEVELOPMENT EFFORT AND EVENTS

Public accounts of the program indicate that initially all went well. The B-1B SPO firmly kept to schedule and cost estimates, except for inflation. The latter had been an expected problem. The congressional cap was for \$20.5 billion in 1981 dollars, with additional dollars added to account for inflation. In March 1983 the first modified B-1A was flown prior to the expected April 1983 date. The second flew its first flight on July 30, a day ahead of schedule. On September 4, 1984, the first true B-1B was rolled off the production line. In October 1984 the first B-1B was flown prior to the expected date in March 1985. The IOC date, with 15 aircraft located at Dyess AFB, was September 1986, well before the 1987 deadline. The SPO was given several commendations for its excellent management, and assessment of the program was positive.¹

However, in late 1986 and 1987 reports began to surface that the program was experiencing technical difficulties and that the flight tests were revealing considerable problems. Investigations into the program pointed out a series of organizational problems that exacerbated the technical difficulties. This section covers the technical difficulties and the organizational problems.

TECHNICAL DEVELOPMENT

The technical difficulties that occurred in the overlapping development and production phases of the program were the ones identified as "new" or "improved" technologies in the 1981 congressional testimony and identified by the SPO in the April 1982 Test and Evaluation Master Plan (TEMP) as likely areas of technical risk.² Some difficulties were actually identified as early as the original B-1A flight-test program; others became apparent in the 1981-1983 time frame. No one could claim the areas of difficulty were a surprise; whether the magnitude of the difficulties had been foreseen is not known.

These technical problems translated into schedule slips as the SPO attempted but failed to keep the program on the ambitious schedule outlined. Nowhere was this more evident than in the flight-test program.

¹See, for example, *Hearings Before the Committee on Armed Services United States Senate*, Ninety-Eighth Congress, Second Session, Department of Defense Authorization for appropriations for Fiscal Year 1985, March 9, 1984. Thomas Cooper, assistant secretary of the Air Force for Research, Development, and Logistics, testified that "the program is right on track. The B-1B is on schedule and within cost and, quite frankly, looking very good" (p. 3303). Later he said, "Basically, as you can see, the RDT&E is beginning to scale down. We are coming to the end of the program" (p. 3317).

²Aeronautical Systems Division, B-1B System Program Office.

The flight-test program for the B-1B was ambitious, driven by the IOC date. It allowed for few delays. As the program progressed the flight tests started off well enough with rollouts and first flights of aircraft B-1A number 2, B-1A number 4, and B-1B number 1 taking place on time. But the flight program became beset by difficulties.

- Fuel leaks had been a continuous problem, resulting in flight delays. These delays sometimes made it impossible to perform all the scheduled tests.
- On August 29, 1984, one month after aircraft number 4 came on for flight tests, B-1A number 2 crashed in the Mojave desert, killing a crew member and injuring two others. B-1A number 2 had not completed its flight-test program. This burden was now placed on the other test articles.
- Poor weather at Edwards AFB was a continuous problem and resulted in cancelled test flights.
- A set of more minor technical problems often caused delays. For example, the fuel center of gravity management system did not properly balance the aircraft, making flight control difficult and stopping several tests.

Despite these delays in testing, in September 1986 the Air Force determined that the B-1B had obtained operational capability. It moved ahead to full production, without remedying all the technical problems. The modularity of the design allowed this approach. The fixes would be incorporated into the aircraft later. In September 1986 the following problems, which held operational capability below that originally envisioned, still remained.

- Key tests had not been completed on major systems, including the offensive and defensive avionics.
- The AIL defensive avionics system, designed to identify and counter a wide variety of lethal threats, could not identify and counter several, especially approaching ground-based missiles. This was a critical requirement for mission-capability.
- The tail warning function of the defensive avionics was supposed to detect enemy attack coming from the rear of the plane and initiate the defensive countermeasures. AIL's system emitted faint warning signals or no signals when flown close to the ground, leaving the aircraft open to missile attack when flying the low-altitude portion of its mission.
- The terrain-following equipment allowed the B-1B to fly close to the ground under adverse weather conditions. It had erratic pitch downs and false terrain

spikes, causing the aircraft to "fly-up" to avoid the imaginary obstacles. This pattern of flight would allow detection and overstress the crew on the long flight.

- Fuel leaks had been a problem in the B-1A, and the SPO had identified them as a technical problem that had to be remedied in the B-1B program. The fuel leak problem continued into the B-1B program, delaying the flight-test program. In 1986 fuel leaks kept several of the aircraft grounded at almost all times, thus operational capability was compromised.
- The bomber had to operate at restricted weights and a reduced flight envelope because of problems with engine stalls and poor functioning of the engine stall warning system. An improved engine stall system was being developed.
- Birdstrikes caused greater damage than expected, jeopardizing the ability of the aircraft to fly at low levels.
- The engines were subject to ice damage.
- There were problems attaining weapons separation.
- The central integrated test system was subject to anomalies, sending false signals of equipment failures.

FINAL TECHNICAL STATUS

Congress was greatly concerned over the technical difficulties with the aircraft, especially those that directly impacted its mission-capability, such as the poor defensive avionics and terrain-following capability. It was also angry that these problems had been evident for some time, that Congress had not been informed, and that the Air Force had declared the aircraft operational despite these problems.

A series of congressional hearings and investigations was made that uncovered the flaws in more detail. Over the next few years the Air Force attempted to remedy the flaws, but problems continued to plague certain technologies. With all the aircraft built, the improved technologies were added to the production aircraft as retrofits. The following is a synopsis of the performance shortfalls that remained with the aircraft as of November 1991.

After several years of trying to develop the defensive avionics, the Air Force finally changed the requirements to meet the technical capability of the design. The final assessment of the electronic countermeasures (ECM) was made in statements made by Colonel Madia, deputy of the B-1B SPO, in May 1991.³ As he explained it, "We changed the objectives on the ECM from handling everything, the top 50 threats. What that meant was

³"Program Director Says Maligned B-1 Is on Road to Recovery," *Defense Week*, Monday, May 13, 1991, pp. 8-9.

to see all 50 threats and in all modes. To see them, automatically process them and automatically jam them. . . What the system now does, it does those functions against the top 11 threats that are most likely to kill the B-1B." He gave the B-1B ECM a grade of 3.85 out of a possible 4.0 for the 11 top threats. It did not receive a 4.0 because the Air Force had recently uncovered a new threat that the B-1B could not handle.

In October 1990 *Defense Week* reported that the last operational tests of the B-1B program completed in August 1990—one year after the last B-1B had been delivered—showed the tail warning set continued to have problems.⁴

The terrain-following equipment was finally released to SAC in February 1987 but with significant restrictions on performance.⁵ As of November 1988, the Air Force had cleared the B-1B to fly at 200 feet with the following restrictions: soft ride, during daylight, in good weather, over flat and rolling terrain. In comparison the requirement is 200 feet, hard ride, at night, in all weather, and over moderate to rolling terrain.⁶ (Soft ride is at low altitude but not closely following the terrain, while hard ride is at low altitude and closely following the contour of the terrain.) This restriction was on peacetime operations only. During wartime the B-1Bs would be cleared to fly in the required conditions.

In addition, the terrain-following function interfered with the other avionics. In September 1986 the electronic countermeasures could not be used with the terrain-following radar. This problem cannot be resolved until the defensive avionics system is finalized,⁷ which has not yet occurred.

As the fuel leaks were simply mechanical problems of creating better seals in the production process, the leaks eventually subsided to an acceptable level.

To improve the flight control of the B-1B, the SPO developed a stall inhibitor system (SIS) and a stability enhancement function (SEF). The SIS development problems were largely remedied by 1988 and by June 1988 aircraft 2 through 18 had been outfitted. The remainder were scheduled for retrofit by June 1990. The SEF was developed later as a scheduled improvement to the aircraft. It was scheduled for installation in January 1992.

⁴"Air Force Admits to New B-1B Problems," *Defense Week*, Monday, October 1, 1990, Vol. 11, No. 40, p. 1.

⁵Subcommittee on Research and Development and Subcommittee on Procurement and Military Nuclear Systems of the Committee on Armed Services, *The B-1B: A Program Review, Report of the Panel on the B-1B*, House of Representatives, 100th Congress, First Session, March 30, 1987.

⁶GAO, *Strategic Bombers: B-1B Cost and Performance Remain Uncertain*, February 1989, GAO/NSIAD-89-55, p. 15.

⁷GAO, 1989, p. 15.

Besides the above major technical fixes, some minor fixes were made. The potential for birdstrike damage required retrofit of some of the outside structure. The potential for ice damage to the engines required a retrofit to the nacelles.

DECISION ENVIRONMENT

Congressional inquiries found that four management or organizational conditions contributed to the B-1B program problems: poor program review, management conditions in the SPO, an overemphasis on schedule, and poor test and evaluation oversight.

Reporting and DSARC Review

At the beginning of the program, it was recognized that high-level oversight was important to ensure that concurrency worked. As discussed before, the schedule could not be met if the program became bogged down in red tape. One way to remove red tape was to have a high-level advocate ready and willing to exempt the program from excessive reporting requirements and overzealous coordination procedures.

The Air Force sought to accomplish this by exempting the program from Defense Systems Acquisition Review Committee (DSARC) reviews (now Defense Acquisition Board [DAB] reviews). The DSARC is the OSD-level review mandated for all major weapon system procurements. It is designed to subject program decisions to an adversarial review of top decisionmakers, representing the many different interests of the Department of Defense. The representative nature of the board acts to ensure that hard questions are asked about all aspects of the program and that organizational consensus is built around major weapon systems commitments. DSARC reviews are scheduled to take place at every major program milestone to ensure that the program is ready to proceed.

The Air Force argued that DSARC review was unnecessary for the B-1B program. The decision to build the B-1B on a completely overlapping schedule meant that the first three decision milestones—to begin development, to proceed to full-scale development, and to proceed to production—had already been made when the program started. Therefore, the DSARC decisions had already been completed at program start-up and approved by the president. To subject the B-1B program to the DSARC process would only impose red tape and excessive reporting requirements on program decisions already made.

To ensure that the program did have a high-level review, Secretary Weinberger decided that the program would report directly to his deputy secretary, Frank Carlucci. The White House and Congress had agreed to the configuration of the program and its decision framework. Any deviations had to be approved by Carlucci. Furthermore, a secretarial

review of the program would take place every two weeks, meaning the Air Force would brief Weinberger. Thus, oversight would be maintained.

Although this seemed a reasonable approach, in fact, it turned out to have some deficiencies. Reports by CBO, GAO, and a congressional review panel found that "several institutional checks and balances normally found in the acquisition cycle of a major weapon development and production were missing from the B-1B program." The lack of a DSARC review prevented any significant airing of the B-1B development problems and their potential solutions.

The biweekly secretarial review could have served this function; however, it was neither intense nor probing. Weinberger testified that at these briefings he asked two questions: "Are we on time and are we within or under budget?"⁸ A scan of the briefing slides to the secretary shows that the main focus was budget and schedule. The B-1B program did keep quite closely to production schedules and cost estimates. It was the promised performance that was missing. Thus, the reporting was usually positive, not indicating that the program had substantial technical performance problems.

Congress found fault with this emphasis from the secretary on down. "The questions that were being asked--is it on time and within budget--missed the key issues of whether all the systems worked and whether the B-1B would meet the threat."⁹

This lack of rigorous review discomfited some in Congress who thought that perhaps the Air Force had not been candid in its reporting to the secretary. This idea was aided by testimony from Krings, the director of Operational Test and Evaluation (OT&E). Krings implied in testimony that the Air Force had not been candid with the secretary.¹⁰ However, this was refuted by the Air Force. General Randolph, deputy chief of staff for Research, Development, and Acquisition, testified that the secretary had been briefed on all of the problems and that Krings had been as well. It was his belief that the Air Force had been candid about all the problems that occurred. However, he did admit that the Air Force had been overly optimistic about its ability to solve the problems in a timely manner.¹¹

⁸*The B-1B: A Program Review*, March 30, 1987, p. 14.

⁹*The B-1B: A Program Review*, March 30, 1987, p. 14.

¹⁰*The B-1B: A Program Review*, March 30, 1987, pp. 14-15.

¹¹Hearings before the Subcommittee of the Committee on Appropriations, House of Representatives, *Department of Defense Appropriations for 1988*, 100th Congress, First Session, Washington, D.C., 1987, p. 415.

SPO Management Constraints

The program structure also set up some very demanding conditions for the SPO management. In essence the SPO was caught between several management requirements: performing the integration function, managing a concurrent program, providing public relations for a highly visible program, and coordinating with a diverse set of actors involved in the highly complex program.

Regarding the first task, the SPO's time was taken up to a large extent in coordinating the technical arrangements among the four primes. Reports of the SPO to System Command Headquarters show extensive numbers of meetings that the SPO sponsored and led between the different contractors. These often addressed interface issues concerning two primes who were using different methodologies to solve technical problems or assignment of responsibility to a particular prime.

As to the second task, the concurrency in the program demanded that the SPO personnel address all issues simultaneously. Issues on basing, support equipment, and training could not be put off if the IOC date were to be met. In the contractual branch, the FSD and LRIP contracts were still being negotiated when the SPO initiated a contractor meeting on the multiyear procurement.¹² In more normal operations these issues are handled sequentially as the program progresses so that personnel can address the issues one at a time.

As to the third task, program visibility meant that the SPO's attention would be diverted by a stream of visitors and public relations activities. The visibility of the program was addressed by creating a B-1 Action Team of key B-1B managers. This group was responsible for tracking and resolving important public issues. It was to meet twice weekly just for this purpose, using up valuable SPO resources to respond to external inquiries.¹³

To perform the last task, this complex a program, whether exempted from reporting requirements or not, demanded extraordinary coordination between different defense offices within and outside the Air Force. For example, the following groups played major roles in the B-1B test program: the SPO, the Air Force Test and Evaluation Center, the Strategic Engine Program Office, the Air Training Command, the four prime contractors, the Department of Energy, the Air Force Weapons Laboratory, Arnold Engineering Development Center, Western Space and Missile Center, the 6585 Test Group at Holloman AFB, and the

¹²Weekly Activity Report for the Deputy for the B-1B, April 22, 1982.

¹³Memo from Major General James Abrahamson, DCS/Systems, to B-1B Action Officers, October 19, 1981.

OSD Office of Operational Test and Evaluation. Their participation had to be coordinated by the SPO in a ceaseless series of meetings, calls, and memos.

Any SPO of a highly visible program might face some similar conditions of numerous visitors and coordination issues. But very few would also have to manage as concurrent a program or one where the government took on some of the integration management function.

Congressional review of the program found fault with the staffing of the program, given its role in integration management. The review found that "it failed to provide adequate numbers of adequately skilled officers to manage the program. Officers who were assigned turned over too rapidly to develop much depth of knowledge and generally lacked the broad experience that a private contractor could field."¹⁴ The Air Force seemed to concur with this assessment. In his testimony General Randolph said, "If there is a 20/20 hindsight fault to be found, and this is purely Randolph, my assessment is the thing not done right is there were insufficient people put on the job to work the problem."¹⁵

Emphasis on Schedule

The B-1B program had an urgent requirement met by a concurrent schedule. When technical problems began to occur, the Air Force had at least two options to consider. First, it could go ahead with the production schedule while maintaining FSD. This would result in poor initial capability, but the aircraft could be retrofitted as improvements were made. Second, it could mature the difficult technologies prior to any further production. Time could be made up on a crash production schedule, and the production aircraft would have full capability.

Both approaches have associated costs and benefits. The first avoids the cost of idle capacity but runs the risk that the aircraft will be built without achieving the capability needed. It meets the immediate schedule requirements of the B-1B program but runs the risk of poor performance outcomes and possible retrofit costs. The second approach incurs the cost of idle facilities but ensures that production decisions are based on mature technologies and real performance attainments. It might meet the immediate performance requirement but run the risk of not meeting the cost and schedule outcomes.

The Air Force, guided by the strong statements made by Congress and the commitment of President Reagan about schedule and cost requirements, followed the first option. It carried on with full production prior to ironing out the technical difficulties of the

¹⁴*The B-1B: A Program Review*, March 30, 1987, p. 13.

¹⁵Hearings before the Subcommittee of the Committee on Appropriations, House of Representatives, Department of Defense Appropriations for 1988, 100th Congress, First Session, Washington, D.C., 1987, p. 415.

program. As such, it produced a plane with lower performance capabilities than required. It met the urgency of the requirement but did not meet the requirement itself.

Congress found fault with this choice. As a congressional review in March 1987 puts it: "The rush to production created an environment where delivery schedules became more important than assuring B-1B capability or maintaining program integrity with an adequate test schedule."¹⁶ Apparently Congress thought the second approach or some like it would have been better. The congressional review and others focused a great deal of attention on the concurrency in the program and the lack of a fly-before-buy approach. Krings testified that he thought the risk of concurrency could have been reduced had there been greater cooperation between different parts of the Air Force. In his testimony, he stated that the fighter community, namely the F-16, had had a great deal of experience on flight control, avionics, and ECM that was not shared with the B-1B SPO.¹⁷

On one hand, the congressional criticism makes little sense. Congress was one of the parties to the agreement and imposed the IOC date as well as the cap. Thus, it was at least partly responsible for the concurrency and the choices made to meet the IOC date.

On the other hand, the criticism makes sense if the issue is really who makes decisions. The decision to ignore technical difficulties and carry on with production was made solely by the Air Force. The angry response of Congress might be because the Air Force did not consult it and did not provide it with information that Congress could use to reevaluate the program.

Role of CSD Office of Test and Evaluation

Finally, several Congress members criticized the OSD Office of Operational Test and Evaluation for not performing its proper role of independent analysis. The congressional review team apparently had reason to believe that the director of OT&E had knowledge about problems with the B-1B and discussed these with the Air Force and Weinberger but not with the Congress.

FINAL OUTCOMES

The program eventually produced the 100 B-1Bs but not without controversy. In 1987 the Air Force took action against AIL for poor performance. It then asked Congress for additional dollars to help solve problems with the defensive avionics and reported that the test program would have to be extended for several years.¹⁸ A report by CBO in 1988 listed

¹⁶*The B-1B: A Program Review*, March 30, 1987, p. 12.

¹⁷*The B-1B: A Program Review*, March 30, 1987, p. 12.

¹⁸Molly Moore, "B-1B Repair Fund Is Requested," *Washington Post*, January 7, 1987, p. A1.

the different options for improving the B-1B performance.¹⁹ The costs of these options ranged from about \$1 billion to close to \$3 billion. Despite the controversy, the production schedule went as planned. The last B-1B rolled off the production line in April 1988 on schedule.

By 1989 GAO was identifying further technical problems with the program. The Air Force requested an additional \$1.9 billion for updates and fixes, of which \$1 billion was associated with fixing ECM (\$476 million to fix the core system, \$250 million for support, and \$489 million to augment ECM with off-the-shelf radar). The cost of the proposed fixes exceeded the congressional cap, and the defensive avionics remained to be proven. The \$1.9 billion is \$1.4 billion in 1981 dollars, about 7 percent of the \$20.5 billion cap. If this expenditure could indeed raise the B-1B to the originally specified performance, the cost overrun would be modest in historical terms. Since the funds have not been approved by Congress, the efficacy of the proposed solution is not known.

Several external factors played a large part in the ensuing battle between Congress and the Air Force. First, the rise of Gorbachev and the fall of the Iron Curtain meant that any program review would consider the B-1B mission and requests for retrofit dollars in light of a reduced threat. Second, the "Ill Wind" probe of illegal defense contractor activities began to erode the congressional support for any defense program. Third, budget stringency put large-scale programs at risk of budget cuts. Finally, three B-1B production aircraft crashed in the period from September 1987 to November 1988. These tragic crashes, while not necessarily reflections of development problems, further eroded the confidence surrounding the B-1B program. These factors contributed to a more critical view of the B-1B program than had existed at its beginning.

The B-1B program became an easy target for abuse. For example, Congressman Les Aspin said: "Frankly, they screwed it up and they didn't tell us about it." A congressional report stated that "the Air Force has been a greater threat to the success of the B-1 bomber than the Soviet Union."²⁰ Critics argued that the B-1B could not perform its mission and that the Soviet threat no longer existed. Worse, now the Air Force was asking for substantial sums for the stealth bomber to replace the B-1B.

The final outcomes for the program are not clear cut. First, the program stayed largely on schedule, as indicated in Table 5.²¹ The initial set of milestones was met, a feat

¹⁹Congressional Budget Office, *The B-1B Bomber and Options for Enhancements*, August 1988.

²⁰Molly Moore, "Air Force Management of B1 'Screwed It Up' Aspin Says," *Washington Post*, March 31, 1987, p. A1.

²¹USAF, *Selected Acquisition Report*, December 1989

not usually accomplished. It is primarily in the defensive avionics that the schedule experienced real delays. These delays continue.

The cost for the final system remains unknown because the ECM improvement costs remain uncertain. The program remained within its congressional cap in base 1981 dollars because Congress refused to fund the \$1.9 billion in improvements the Air Force requested (\$1.4 billion in 1981 dollars). Table 6 shows total program cost divided into Research, Development, Test, and Evaluation (RDT&E) and production. Although the total cost just equals the \$20.5 billion cap (in 1981 dollars), the RDT&E component was about half a billion higher and the production component about half a billion lower than projected originally.

Table 5
Schedule Outcomes

Milestones	Planned Dates	Actual Dates
R&D contract award	Jan 1982	Jan 1982
Production contract award	Jan 1982	Jan 1982
Initial Operational Test and Evaluation start	Apr 1983	Mar 1983
First flight B-1A #2	Apr 1983	Mar 1983
First B-1B flight	Mar 1985	Oct 1984
OT&E complete	Jun 1986	Oct 1990 ^a
IOC delivery	Sep 1986	Sep 1986
Production complete	Jun 1988	Apr 1988
Electronic Countermeasures retrofit complete	NA	Jul 1994 ^a

SOURCE: U.S. Air Force, *B-1B, Selected Acquisition Report*, 1989.

^aIndicates a change to the development schedule.

NA: not applicable.

Table 6
Selected Acquisition Report, 1989 Cost Estimates

1981 Base Year Dollars (in billions)	RDT&E	Procurement	Total
Development estimate	2,538.9	17,961.1	20,500.0
Current estimate	2,975.5	17,307.5	20,283.0
Difference	+436.6	-653.6	-217.0

SOURCE: U.S. Air Force, *B-1B, Selected Acquisition Report*, 1989.

These cost estimates include the cost of the improvement program as approved and appropriated in 1989. However, they do not include the cost of meeting the performance originally required. That requirement has been reduced.

The performance of the B-1B, while still perhaps an improvement on the B-52, is not capable of meeting the requirements originally established in 1981. SAC declared the aircraft to be operational. It meets the current mission requirements established in 1991 but only because those requirements were reduced from the original 1981 requirements to meet technological realities. The B-1B is able to fly in the flight envelope originally envisioned. But it cannot adequately counter the air defenses that were originally included in the requirement. With additional funding from Congress and with a further flight-test program, the B-1B might eventually be able to meet the original program goals.

The program had further costs to the Air Force. Most important, the Air Force's congressional relationships have suffered. For example, during the last two years the Air Force has applied to Congress for more funds for the program. Congress has provided some of the requested dollars but only under the condition of imposing further oversight on the program and after arduous and contentious review of the program.

IMPLICATIONS

To summarize, the management approach created at the beginning of the program eventually caused difficulties during the development stage of the program. These difficulties arose as the technical development proceeded. These problems led to poor program outcomes in both the long and short term.

The Air Force did indeed get a bomber in time to counteract the window of vulnerability. But the bomber did not meet the originally specified requirement. The bomber might never have that capability. With a new and different relationship between the United States and the countries that made up the former Soviet Union, the United States might never need that capability. The Air Force estimates that a 7 percent cost overrun would substantially increase the performance of the aircraft. Congress, perhaps not finding this credible (or important), has not provided the funding.

The clumsy policy tools approved at program initiation failed to take into account their effects on the SPO when technical difficulties arose. By constraining two outcomes (cost and schedule) to a small range, the management strategy inadvertently reduced the SPO's ability to manage risk well.

The implications of the development program are fairly clear. Although some fault can be found in the SPO management of the development phase once it began, the source of much of the difficulties that followed lies in the early choices made by the higher levels of both the executive and legislative branches of government and imposed on the SPO. The one major exception might be that the Air Force did not staff the SPO adequately. But this only exacerbated an already difficult situation. The lessons are clear for specific acquisition policies.

- Concurrency did not produce the expected results due to the technical risk.
- The budget cap produced unanticipated consequences. It prevented a technical hedging strategy and eroded the ability of the SPO to meet the performance required in a timely manner.
- The factors that led to the poor performance outcomes were knowable and known in advance to be potential problems.

7. CONCLUSIONS

The story of the B-1B acquisition is ambiguous. Asking whether it was a success or failure is something like asking whether the glass of water is half empty or half full. It depends on one's point of view.

Michael Brown produced an insightful view of the program.¹ Rather than narrowing in on the program faults, he reviews those aspects of the program that encouraged what success was evident. He begins by noting that the program was accomplished close to the original budget and that it will meet most performance standards, although certainly not on schedule. These are feats that have not been accomplished frequently.

He notes that one factor leading to this success was that the cost, schedule, and performance targets were common knowledge and had been agreed to by all parties. Thus, when the program problems were publicized, the parties to the agreement could immediately press for improvements.

Given the above and the level at which the management strategy was set, the program was subjected to an unusual amount of scrutiny. This high-level attention was beneficial for keeping the program on budget and schedule. The Air Force knew from the beginning that a group of high-level officials and congresspersons was waiting to pounce on the program if it did not meet expectations. Brown admits that the executive branch oversight was less than perfect, but it was certainly more than any other program received. It did act to keep the program cost and schedule within bounds.

These are the positive attributes of this program. A more negative view can be taken, especially as regards risk management.

First and foremost, in highly visible programs like that of the B-1B, decisions are taken out of the SPO's hands and made by higher levels of government. These levels use political negotiation processes that do not necessarily arrive at solutions supported by normal acquisition policy or advocated by career acquisition experts. In the B-1B case, these levels imposed a management strategy that greatly increased the potential for negative outcomes. In addition, negotiations at these levels tend to underplay technical risk, as actors attempt to gain the best advantage in terms of committed dollars.

One constraint imposed was a strict IOC date, which in turn mandated a concurrency strategy. The problem evidenced on the B-1B was not concurrency itself, but concurrency

¹Michael Brown, "B-2 or Not B-2? Crisis and Choice in the U.S. Strategic Bomber Programme," *Survival* July/August 1988, pp. 351-366.

combined with high technical risk in areas essential to mission-capability. In the B-1B example the Air Force took on a program with high technical risk, and its performance suffered when the technology development did not proceed as planned.

Another constraint imposed was the congressional cap. The benefits of this policy were clear. Dr. Cooper, assistant secretary of the Air Force for Research, Development, and Logistics, in 1984 praised the cap because it allowed stability in the program.² Cooper said, "As a resource manager in the Department, though, I would like to make the comment that having the \$20.5 billion cap on this program has done more for us in terms of managing that program and keeping some of what would be a very useful capability. So it has been a very, very useful management tool and that agreement that was arrived at between the Congress and the President I think has done an awful lot to stabilize the program." However, it also had associated costs. The dollar amount left no room for failure, as required in programs with technical risk.

The high-level emphasis on cost and schedule outcomes created incentives to downplay the technical difficulties and proceed with production even though the technology was not proven. This emphasis was translated into program performance indicators that encouraged further movement away from a conservative approach to technical development.

As Weinberger testified, he really focused on two indicators of program well-being: cost and schedule. In a highly concurrent program the technical difficulties would not impact on the schedule or cost until production aircraft had been built. While FSD dollars would mount, this would not necessarily result in exceeding the cap until later in the program.

The final outcome under this set of constraints was an aircraft produced close to on-time and on-budget that did not have the high level of operational capability planned. This is a result no one wanted. The potential good news is that the performance remedy advocated by the Air Force represents only a 7 percent cost overrun. The potential bad news is that it may not work and the money might be better spent elsewhere.

Finally, the technical problems that manifested themselves in the program were in areas that were predicted or were easily predictable. There really were no surprises in terms of which technologies caused problems or how new management roles for the Air Force might present an additional challenge to the SPO. It was really the strategy that was at fault. Once committed to it, the parties involved could not consider the outcomes surprising.

²Department of Defense Authorization for Appropriations for Fiscal Year 1985, *Hearing Before the Committee on Armed Services*, United States Senate, March 9, 1984, pp. 3348-3349.

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Appendix DEFINING RISKS

This section briefly examines how development managers view risk, risk assessment, and risk management and suggests simple ways to view these concepts to help in understanding the foregoing Note.

Weapon system development is an inherently risky activity. Most people would agree with that statement, but few would agree about precisely what it means. Most would agree that it suggests that system development is not a predictable process. Many would go further to say that the activity involves many surprises with negative outcomes. That is, the word "risk" suggests not only unpredictability, but setbacks. This is especially true for risk management. The purpose of those who manage risk is to ameliorate the negative effects associated with the unpredictability of a weapon system development.

The very unpredictable nature of risk itself, however, tends to defy further formal definition. Any attempt to be precise about what risk is tends to give up some aspect of unpredictability. Where profound uncertainty exists, it is impossible—and perhaps even misleading—to be precise about it.

A REALISTIC VIEW OF RISK TO USE IN ANALYSIS

The dominant analytic definition of risk is probably that of economists and decision theorists, who emphasize unpredictability. For economists, risk increases as the variance of outcomes associated with the process increases.¹ To illustrate, consider the two distributions in Figure A.1. The outcome of a process is represented on the horizontal axis in terms of a single metric of performance. *Subjective* probability density lies on the vertical axis. With this definition, distribution D1 is riskier than distribution D2 because D1 is more diffuse than D2. D1 is riskier even though the central tendency for D1 is well above that for D2 and would be riskier even if D1 strictly stochastically dominated D2.²

Now suppose that D1 and D2 represent the expected outcomes of two different approaches to developing a weapon system. The metric of performance might be the

¹Many economists would go further to distinguish risk and uncertainty. Risk occurs when the unpredictability is associated with the outcomes of a well-understood stochastic process; uncertainty occurs when unpredictability results from outcomes of a poorly understood process. A related distinction will be useful below.

²That is, suppose that we imagine random draws from both distributions simultaneously. If we believe that outcomes for the two distributions are correlated so that the outcome for D1 always dominates that for D2, then D1 strictly stochastically dominates D2.

probability that a fighter aircraft prevails in a standardized air-to-air engagement with the enemy. Viewing these alternatives, weapon system developers would all agree that D2 represents the riskier approach. They would justify this position by pointing out that poor outcomes are more likely with D2 than with D1. Going further, some might be willing to set a minimum standard of success for the aircraft and characterize risk as the subjective probability associated with outcomes lower than this standard. For example, if the standard were S in Figure A.2, which recreates the distributions in Figure A.1, the risk associated with each alternative would be proportional to the shaded areas, R1 and R2, representing the subjective probabilities that the aircraft designed by each process failed to meet the set standard.

The density functions in Figures A.1 and A.2 are essentially *risk assessments*. Risk managers cannot effectively make such assessments independently of the policies they intend to use to manage risk. That is, they effectively view *risk management* as a way to alter the shape of the distributions shown. Some of these policies are things the manager can put in place today, such as an acquisition plan, system specifications, a contract, a test plan, and so on. Some of them cannot be made explicit in advance. The manager must expect surprises whose details he cannot know and plan for in advance. These surprises, which will occur repeatedly, will each presumably alter the manager's risk assessment and force him to change policy in some way to get risk under control again.

Viewed in this way, risk management begins to look very much like the general management of a development program. And, in fact, development managers draw little distinction between the two. In a sense, the central task of a development program is to eliminate basic uncertainties about a new design so that it can be transformed into a useful product. But managers do not generally think in terms of subjective probability densities like those presented above. They think more in terms of contingencies: What would happen if *this* happened? Routinely, how likely is it? What kind of trouble would it cause? What can I do now to mitigate that trouble? What kind of resources or staff would I want then to deal with it? The metaphors above reflect the understanding that managers generally focus on surprises that can hurt them and seek ways to mitigate the effects of these surprises or events.

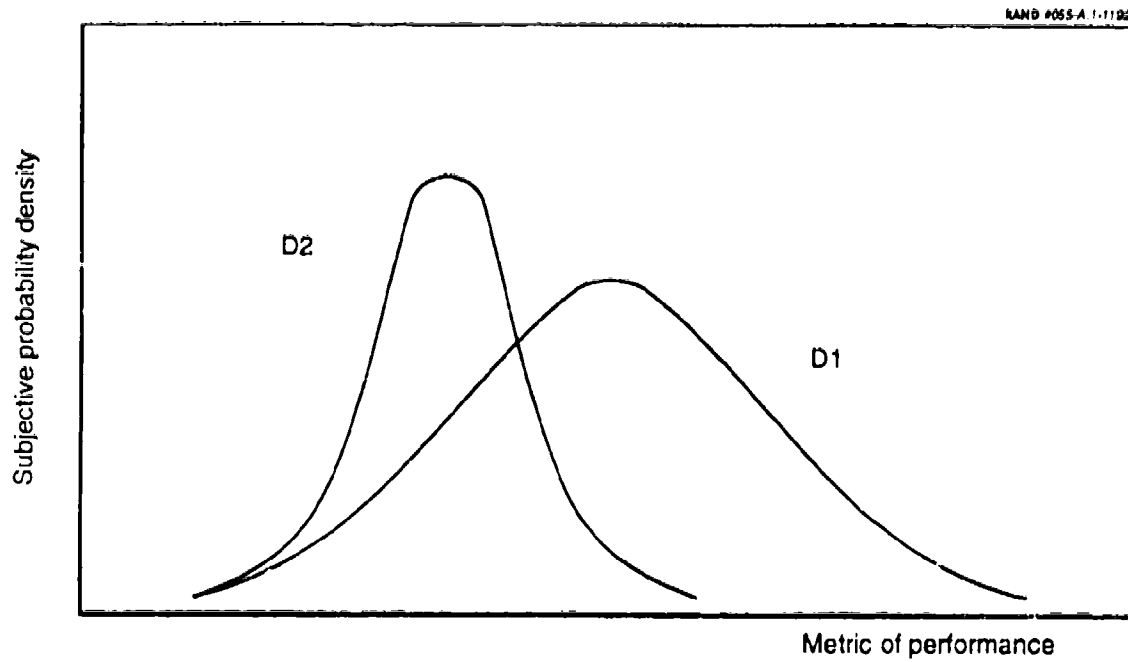


Figure A.1—Subjective Probability Density Distributions for Two Programs

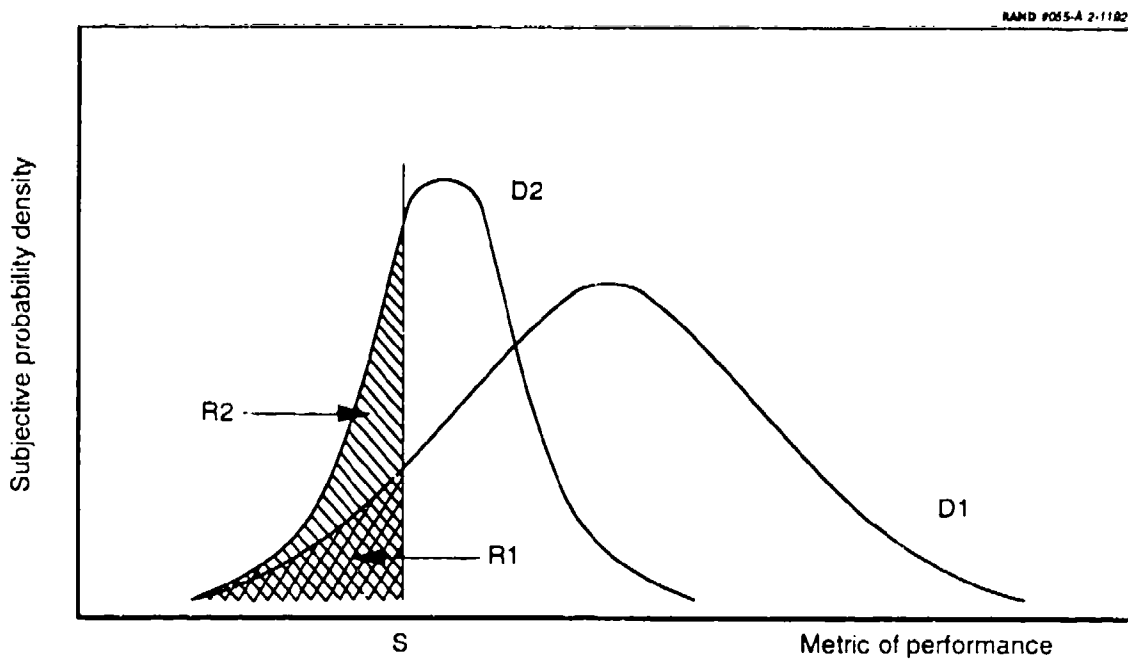


Figure A.2—Risk Associated with Two Weapon System Development Programs

Program Attributes Affected by Risk

When surprises occur, they can affect the program in a number of ways. First and foremost, they can affect the probability that the program will survive to yield a useful product of some kind. With successful program completion, they can affect the resources and time required to complete the program. These are the "cost" and "schedule" criteria normally associated with development. They can also affect final system "performance" in a wide variety of ways. Traditional measures of system performance emphasize combat capability and can normally be measured in a variety of ways specific to each system. Producibility and production cost for the system round out the performance factors relevant to the manager.

Sources of Risk

Managers look for surprises that increase risk in two places. First, development takes time, and while it occurs, the world outside the program can change, precipitating surprises for a development. Most basically, changes in the threat can affect willingness to continue funding the program or the requirements set for the final product. Changes in technology can affect the availability of subsystem capabilities that the development relies on or the need for the system under development. Changes in the economy can change the cost of the development itself or of the final product or the availability of funds to maintain the development as expected. Changes in the Air Force testing and evaluation community can affect the availability of test assets. All of these factors are essentially beyond the manager's control. He can reduce their effects generally by keeping the length of a development down, so that fewer opportunities for surprises arise over the course of the development. More likely, the manager must anticipate specific kinds of surprises and tailor individual responses to each one.

Second, even if the world outside the development remains stable, surprises can be expected within the development. Development efforts can take more time or resources than expected to reach a particular performance improvement. Certain technical goals set in the program can turn out to be infeasible. The manager has greater control over such factors but can still not expect to eliminate surprises of this kind.

Risk does not always come from surprises; managers can introduce risk into a program by their own action. As a development program is normally defined, a manager will have a hard time meeting the multiple goals. To increase the probability of program survival early in its life, the manager must make the program look attractive relative to competing alternatives. Hence, the manager generally attempts to hold down goals for development cost and schedule and increase the performance goals of the system. To the extent that such

goals are adopted as standards like those in Figures A.1 and A.2—that is, a program fails if it fails to meet all of these goals—these actions actually increase the risk associated with a program. In most cases, however, the manager must accept such risk to reduce the risk of losing overall support for the program to a competing development program. Managers well understand this tension between the goals of program survival and other goals of the program; they view it essentially as a price of entry for conducting development activities. In the end, however, such behavior means that the manager cannot expect to meet all the goals and must expect to make trade-offs about how to allocate shortfalls among goals. However, the ability to make these trade-offs might be hampered by pre-existing policies or strategies that limit the manager's actions. In fact, these policies or strategies can impose risks on a program. This theme is explored in the foregoing Note.

When surprises occur, the manager must again make trade-offs among these factors. Some surprises will loosen constraints on the manager; an unexpectedly high performance outcome in one area might allow the manager to reduce risk associated with performance in another area or to hold the line on the costs or schedule of development. Negative surprises, on the other hand, will lead a manager to spread the negative effects across goals. A test failure, for example, may lead to a schedule slip and additional development work to achieve the initial performance goal at the expense of schedule and cost goals.

How a manager makes such trade-offs should depend on the relative priorities placed on different goals, based on either guidance from above or personal goals. These priorities will differ from one development program to another and perhaps change over the course of a development. Patterns in such trade-offs are a primary concern in this Note.